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PREFACE.

THE present work is one concerning which a few words of prefatory notice may be deemed necessary. It aims at nothing more than to give the beginner in the study of Zoology or Botany a comprehensive view of the great life-fields which are seen to lie before him, from the standpoint of an observer in the common territory of Biology. But the Author would hope that the work may also prove acceptable to the non-technical reader, who may wish to gain a general idea of the manner in which the wondrous cycle of existence is carried on and maintained within the living organism.

Each succeeding year demonstrates more forcibly to the teacher of Natural Science the high importance of making his pupils thoroughly acquainted with those recognised principles on which the study of living beings is conducted. Looking on the present effort, therefore, as a sketch or rough picture, the Author has sought to draw broad outlines, rather than to fill in the details of a highly technical or completed work. He has desired to lead the student, as a passing traveller, through the great biological tract; halting in the ramble only to point out those more prominent points which will serve as familiar landmarks to guide and direct him in a subsequent and more extended survey. The information to be gained in such a manner forms the only sure basis

on which a solid superstructure of systematic knowledge may be afterwards built up.

Thoroughly aware of the theoretical, as well as the controversial nature of many stages in the biological journey, the Author has endeavoured, so far and as plainly as he could, to state the *pros* and *cons* of such debateable subjects. But he has not, at the same time, hesitated to express an individual or party opinion as to the merits or demerits of any particular school of thought or theory. A fair statement of facts, it will be allowed, is not invalidated by an honest expression or advocacy of the side to which an author may be disposed to lean.

The Author has thought that the aim and end of a student's "guide-book" would be better fulfilled by adopting a style often bordering on the conversational, than by writing in a manner which, if more strict and formal, would obviously prove less interesting and explanatory to beginners in the science.

With the view of aiding the junior student especially, a Glossary, containing explanations of the more technical terms used in the text, has been appended to the work.

The illustrations, taken from various sources, have been drawn on wood by the Author. A few are original, and the Author has been guided in his selection of the entire series, from the knowledge of the diagrams required to illustrate a course of prelections on the "Principles of Biology."

EDINBURGH, *January* 1874.

LIST OF ILLUSTRATIONS.

CHAPTER I.

Definition of "Natural History" and "Biology"—Relations of the Organic and Inorganic Series—Classification of the Natural Sciences—Characteristics of Organic and Inorganic Objects—Form—Chemical Composition—Intimate Structure—Mode of Increase—Cyclical or Periodic Change.

THE term "Natural History," used in its widest significance, has hitherto been employed to designate that department of scientific inquiry which deals with the structure and relations of the objects which exist in the world around us, and of which, indeed, the universe itself is composed. But a very little consideration will at once show us, that the term so employed has a decidedly compound nature, in that it may be said to embrace or include several distinct and individual sciences. Thus, in one way, by the name "Natural History" we may collectively designate the kindred sciences of Botany and Zoology; or we may employ the term as merely synonymous with the last-mentioned branch of inquiry; or lastly, and in its wider meaning, we may speak of "Natural History" as including the sciences of Zoology, Botany, and Geology, together with other and allied departments of science.

Of late years, however, important, and at the same time beneficial, changes have been wrought in the nomenclature of the "Natural" sciences, and a new term, that of "Biology," has been introduced into the terminology just referred to. This latter name—"Biology"—may be correctly enough translated by the words "Science of Life," or of "Living Beings;" and whilst it thus includes several departments formerly recognised under the term "Natural History," its meaning is obviously more

restricted and defined than that of the older name or expression.

But although the term "Natural History" has, in this way, been broken up, and although its former significance is almost entirely lost, yet, scientifically, the name is still used to conveniently express and include all those departments of inquiry which investigate the relations of "Natural" objects; and, employed in this latter and extended sense, it therefore includes many branches of inquiry which formerly lay beyond its meaning and import. This more recent arrangement will be presently noticed when treating of the classification of the various departments of Natural Science, but these preliminary observations will serve to impress on the minds of beginners the altered relations of this constantly recurring term.

The aim and scope of that department of scientific knowledge known as "Biology," is therefore the investigation, in its fullest sense, of *living* beings in all their relations, whether to each other, or to the objects by which they are surrounded. The term—derived from the Greek, *bios*, life, and *logos*, a discourse—sufficiently explains itself, and it will require but little thought to perceive that the wider name and science of Biology includes the two great provinces of inquiry which deal with the corresponding series into which living beings are divided. As the youngest and least erudite amongst us knows, the Animal World on the one hand, and the Plant World on the other, are the provinces or series referred to; and the sciences of Zoology and Botany could also be readily suggested, as those which investigate for us the respective details of animal and plant existence.

Hence the "Science of Life," or "Biology," includes the two sciences of Botany and Zoology. But as we gaze on the external world, we find that a complete and thoroughly comprehensive view of the wide field of Nature would necessitate our recognition of a third group of objects, in addition to the two groups we have already perceived. This third group embraces objects devoid of

life, and for these we employ the general term "Minerals;" and the Mineral Kingdom, therefore, forms the third of the great Natural Kingdoms which, from our earliest years, we have been accustomed to recognise.

Beyond this primary classification of natural objects, however, a further division has to be noticed. In speaking of these objects we are accustomed also to recognise their division, according as they are living or lifeless, into two "Series," known as the "Organic" and "Inorganic" series. And these latter are terms, with the meaning of which it will be advantageous for the student to become acquainted. By anything being "Organic," we broadly understand that it possesses life, or is alive; whilst an "Inorganic" thing, on the contrary, is one which is lifeless, or destitute of vitality. Thus the "Organic Series" includes the animal and plant worlds; whilst the "Inorganic Series" contains the mineral world, and all objects destitute of life. It is therefore the province of Biology to investigate the relations of the Organic Series; the consideration of the Inorganic Series falling to the lot of the Chemist, Mineralogist, Natural Philosopher, and Geologist.

The following table may serve to render clear the arrangement which has just been detailed:—

Divisions of Natural Science or History.	Division of Natural Objects.	Primary Divisions, or "Series."
Biology ("Science of Life") includes	I. Animal World (Zoology) II. Plant World (Botany)	These forming the Organic Series.
Mineralogy, Chemistry, Natural Philosophy, and Geology, include	III. Mineral World	This forming the Inorganic Series

Although, as implied by the term Biology, our con-

siderations are to be devoted to an examination of the principles on which the study of living beings is conducted, yet we cannot, at the present stage, leave the inorganic series wholly out of consideration. At the outset of our studies a few questions of great interest and importance await us; and even in the case of juniors in the school of natural science, it is neither wise nor right that these questions should be passed over or omitted.

The preliminary questions to which I allude, bear chiefly upon the distinctions which the biologist is led to draw between living and lifeless things, and between animals and plants. And to the popular mind the thought of the actual necessity for drawing such distinctions, may, and not inaptly either, suggest itself. "Why," it may be asked, "do we require to draw and define lines of demarcation between living and lifeless things, or, for that matter of it, between animals and plants?" But, on the other hand, it is the province of a true scientific method to be in every way thorough and exact. And without, at first, perhaps, fully recognising the necessity or importance of clearly understanding the relations between any two groups of objects, yet we must needs have these relations clearly in view; since we may be called upon to discuss questions concerning such relations, and the correctness of our judgment and reasoning will most surely depend on the estimate we have previously formed of them. This holds particularly true of the relations between the animal and plant worlds; the scientific observer, as we shall hereafter see, setting at nought most, if not all, of the means and ways by which the ordinary or unscientific observer would seek to separate the one great group of living beings from the other.

The differences or distinctions which the biologist is led to draw between organic and inorganic things are included under the five heads of—(1.) *Form;* (2.) *Chemical Composition;* (3.) *Intimate Structure and Arrangement of Parts;* (4.) *Mode of Increase;* and (5.) *Cyclical or Periodic Change.* To the consideration of each of these points, therefore, we may devote a little attention.

Firstly, then, living bodies are distinguished from lifeless or inorganic bodies, by differences in *Form* or *General configuration.* Inorganic things may be destitute of any distinct or definite shape, in which case the term "amorphous" is applied to them. Their form may, in some instances, be inappreciable at first sight, but generally, and without much trouble, inorganic things are ascertained to be bounded by straight lines and by plane surfaces. If we select a crystal of any kind as an example of an inorganic body, we can readily enough admit the truth of the definition just given. Its facets and angles offer definite points of arrangement; its boundaries are straight lines, and its surfaces are plane or flat surfaces.

A living body, on the contrary, is generally bounded by curved lines, and by convex or concave surfaces; or, if we care to extend the definition, we may use the words "irregular surfaces," as serving to include those living bodies, which may seem to fall without the boundaries of a definition savouring of the strictly mathematical kind. At any rate, there is little chance of confusing the outline of the living organism, with the generally mathematical boundaries of the inorganic body.

Look at the body of a horse, for example, or of a fish; or extend your glance throughout the wide area of either plant or animal life, and notice how form and symmetry partake of the curved outline. Indeed, so accustomed have our ideas and thoughts come to be associated with symmetry, that we describe the "line of beauty" as a curve; and in the shape and symmetry of animal or plant form, we rarely or never see a perfectly straight outline, but in its place a graceful curve or undulation.

Then, as this curved condition appears to be invariably connected with the outline of the living organism, so also are the surfaces of the organic body similarly convex or concave. Rarely or never do we see in a living body the flattening and strict planes of the inorganic object; but with wavy curves, and bulgings, and shallows, the symmetry and contour of the living being is at once beautifully and gracefully formed. The foregoing remarks with

regard to form and general configuration must, of course, be held as applying to the living body as a whole, and generally, although not invariably, to its parts also. But in some instances, the terms of the definition would appear to be infringed, as, for example, where mineral concretions are developed, normally or abnormally, in the textures of the living body. Such structures will be found, irrespective of their origin, to present the characteristics of inorganic things. The definition as here employed, however, includes all the essentials for distinguishing, on this first head, between things living and things lifeless.

Secondly, the study of their *Chemical Composition* affords grounds of distinction between organic and inorganic objects. The science of Chemistry deals with the intimate composition of bodies, and in analysing substances of all kinds, the chemist finds that they consist or are made up of a number of bodies which themselves are ultimate, or which, in other words, cannot be split up into two or more bodies of different kinds.

Such ultimate bodies are known as "elements," and of these bodies Iron, Sulphur, Zinc, and Arsenic, may be selected as familiar examples; whilst certain bodies, existing in their single and ultimate state in the form of Gases—such as Oxygen, Hydrogen, and Nitrogen—also fall under the classification of "elements," since they cannot be analysed into two or more gases of different composition.

The information, therefore, which the chemist has to convey respecting the relative composition of living and lifeless things may be generally stated as follows. In inorganic bodies a plurality or considerable number of elements is found, and these elements may exist in the inorganic body, either singly, or in combination with each other, in which latter case they form "compounds." The "compounds" so formed by the union of the elements of lifeless bodies, are not prone to resolve themselves into the individual elements of which they are composed; and lastly, the number of elements in such inorganic "compounds" is never very great.

In living or organic bodies, on the contrary, the chemist finds but few elements; these few, however, rarely existing in their single and elementary state, but generally forming among themselves very elaborate compounds. And in living bodies, as opposed to inorganic things, the chemical compounds are prone to resolve themselves into their respective elements; in other words, the compounds of organic objects are exceedingly liable or predisposed to "decompose." A simple and ultimate fact in the chemical composition of organic bodies, is the invariable presence of water; and this latter fact is not without its due weight and importance, in the face of the considerations which await us, when we discuss the probable nature of life and vitality.

Lastly, it may be a useful fact to bear in remembrance, that the elements Carbon, Hydrogen, Oxygen, and Nitrogen, are the "essential" elements found in the composition of animals and plants. These are so termed from their invariable presence in organic bodies, and in contradistinction to other elements of less frequent occurrence, which latter are accordingly known as "incidental" elements.

Thirdly, in the details of *Intimate Structure and Arrangement of Parts*, we find a further means of distinguishing between the organic and inorganic series. The lifeless crystal, as the type of the inorganic body, presents throughout its substance, when pure, and apart from chemical considerations, a perfect similarity of structure. To use other terms, a homogeneity or sameness of structure is characteristic of inorganic bodies. A bit of chalk, for example, to use a homely phrase, is chalk "all over;" and of a block of coal, a lime crystal, or any other and ordinary inorganised body, the same remark holds good. Nay, if we pulverise our crystal to the finest state of division—so finely, indeed, that the naked eye cannot discern with any degree of precision the separate particles, the microscope will, nevertheless, demonstrate to us that each minute particle or crystal will bear all the essential characters which marked and distin-

guished the entire crystal as a whole. Each particle, in fact, will be the prototype of the mass from which it was derived.

On the other hand, a living body generally consists of diverse or heterogeneous parts. Dissimilarity of structure may be said to characterise the living body, just as a sameness or similarity of structure is characteristic of the inorganic thing. And between the diverse parts of an organic body, that is between the tissues or organs of which it is built up, there exist certain definite and decided relations, evinced and manifested after a defined order or succession. The want of anything in the lifeless body, approaching in nature to such relations, sufficiently indicates the want of parallelism on this special point. In the lower forms of life, it is true, these relations may not be either strongly or appreciably marked ; but even in the case of these lowest organisms, their intimate structure, as distinguished from that of the inorganic body, affords perfectly clear and unmistakable grounds of distinction.

Fourthly, the *Mode of Increase*, in the case of a living and of a lifeless body, offers a very marked ground of separation and distinction. A typical example of the mode of increase in an inorganic body is seen in the case of those naturally-formed calcareous or limy pillars which depend from the roof of many limestone caverns, and which are known as "stalactites." Such a pillar, often of very large size, is formed by the slow dripping of water holding in suspension a large quantity of lime. This water percolates through the rocks forming the roof of the cavern, and thus drops on to the floor beneath. As each drop of water trickles slowly downwards, it leaves behind it, and before it drops on the floor of the cavern, a small proportion of its calcareous burden, which thus remains attached to the roof of the cave. Gradually, and as time rolls on, this deposition of lime particles continues, until at length we find a solid pillar-like structure formed, which depends from the roof into the cave below. Or, in a similar manner, we may find that the

water dripping from the roof, or from the "stalactite" itself, on the floor of the cavern, may gradually deposit lime particles, to form in time a pillar springing from the floor towards the roof, and which is known as a "stalagmite;" this latter structure being in every particular, save in position or point of origin, the prototype of the "stalactitic" growth.

How, in either case, has the lime-pillar been formed? By what process has the gradual increase in size been carried on? Simply by the slow and gradual deposition of new particles of lime on the outside, or on top of those particles which were already deposited. The process is a purely mechanical one, that of adding to the substance of the stalactite by fresh additions to its outside or external surface; such a process, indeed, as a child endowed with sufficient patience might imitate in the construction of a pillar of clay, by sticking new particles of matter on the top of those which were already placed. Each drop of water, bringing its quota of calcareous matter, left behind a proportion of its burden attached to the already-formed material. The process, therefore, merely demands a certain rou a mechanism, and a sufficient period of time. And to this mode of increase, namely by the addition of fresh particles of matter to the external surface, the term "accretion" has been applied.

Contrast now with this state of matters the mode of increase of a living body, and observe the essential and characteristic differences which are at once and readily perceptible. The living body increases in size, or adds to its substance, by absorbing matter from the external world, by receiving such matter into the interior of its body, and by "assimilating" the matter so received—that is, by incorporating the matter with, and converting it into the substance of which its body is composed. As opposed to the process and term of "accretion," the living body may be said to nourish itself and to increase by a process of "intussusception." The lifeless body thus increases from without: the living body is built up from within.

The elaborate processes included under and implied by the terms "assimilation" and "intussusception," are performed by the digestive and absorptive systems of the organism. These special functions, as we shall afterwards see, are as distinctive of the living organism, as we now notice the mere result of their working, to characterise and distinguish the living body. The term "assimilation" therefore, means something more than the mere reception within the body of foreign material. It carries with it the sense and meaning of such matter being further subjected to a process of alteration, of elaboration, and finally of absorption, in a new form into, and incorporation with, the tissues which it is destined ultimately to nourish and support.

Such a process, therefore, so far from being merely or in any way mechanical, is of the kind we ordinarily term "vital;" in other words, the process of nutrition, or that by which a living body nourishes itself, is dependent upon, and follows, the exhibition of those complicated phenomena, which, taken collectively, constitute what we know as "life." And thus the living body alone and truly "grows:" the lifeless or inorganic object merely increases in size. The "growth" of the living organism is thus carried on in virtue of the several actions and phases which are essentially concerned with the elaboration internally of matter derived from the outside world.

Fifthly, and lastly, we may distinguish between organic and inorganic bodies, under the head of *Cyclical or Periodic Change.* Inorganised bodies present in their history no series of defined actions or processes which tend to effect changes or alterations of a similar character in their substance or history. They are, it must be allowed, acted upon by the chemical and physical forces which are everywhere and ceaselessly at work in the universe around us. But within themselves, they possess no source of active or potential change, and are solely and passively acted upon from without.

stone or boulder, for example, in the centre of a

plain, will exhibit but little change throughout a long course or cycle of years. The rains and frost may effect some alteration in its outward aspect; the chemical action of the atmosphere may affect the constituent parts or elements of which the stone, chemically speaking, may be composed. But beyond these purely physical alterations, the history of the boulder will be one without variation or change. And what is true of the boulder is also true, in a greater or less degree, of every other inorganised body.

Very different, however, is the case of the living being. Its entire existence is made up of changes and alterations. Its entire "life," as we know it, from beginning to end, consists of defined stages, each accompanied by characteristic phenomena, which vary widely in the phases or actions through which they are manifested. From the commencement of its existence, ceaseless action and consequent change are to be perceived as pre-eminently characteristic of the living organism. Its growth, its progress towards structural perfection, its maturity, its decline and decay—are each and all periods and phases, heralded and accompanied by, and manifested through, active and characteristic changes.

Nor less striking are the changes, which, in its relations to physical and chemical forces and laws, the living body presents. The physico-chemical actions, which, unopposed, effect change and alteration on the lifeless or inorganic mass, are made subservient in the living organism to the ends and aims of its existence. The living body has a chemistry and a system of physics peculiarly its own. But further, it may not only be the source of active change within itself, but may also effect changes in other bodies or things. It may be the source of various forms of energy or power, and in this capacity may produce light, heat, or electricity, which in turn may affect either beings similar to itself, or the inanimate and lifeless material by which it is surrounded. It may possess the power of independent motion, and in virtue of this power may move about from place to place, com-

tial; and to leave the student without at least putting him in possession of facts as they stand, would be to neglect the most important of the principles and theories with which the biologist has to deal: Since questions concerning the nature of life and vital action are, at the present time, of the fullest and deepest import to every student of the great life-sciences. Newspaper and magazine literature teems with discussions respecting the life-theories of the past as compared with those of the present; and, if only to enable us to keep abreast with the tendencies of everyday life and thought, the present subject demands somewhat extended notice and comment.

The opinions of the earlier workers in biological science regarding the nature of life need not be discussed at any length in considering the question in its more modern aspects, and under the light of modern research. In this, as in very many other matters, the ancients were quite content to theorise, and to conceal, under the idea of an abstract term or name, their ignorance of the cause or source of any given action or series of phenomena. The ancient theories of the origin and nature of life embody much that is mythical and fabulous, yet we may trace through the mist of superstition and ignorance a few beams of the true light, struggling and feeble, no doubt, but asserting their power and presence as auguries of the higher hopes and certainty of the future.

Passing over the dark ages of history, in which knowledge, social, political, or scientific, gained little or nothing that was new or useful, we step at once, in the consideration of life-theories, into the arena and sphere of modern thought. A transition this, comparable, in detail and results, only to the rapid change from the gloom and darkness of a dungeon to the bright sunlight of the full and brilliant day. With the advent of what may be termed the philosophical era of thought, matters biological, along with the condition of science in general, underwent a very great, and at the same time beneficial change. New theories and ideas rapidly supplanted the old time-honoured thoughts, which, from sheer staid age and

respectability, had assumed an importance not to be lightly estimated or set aside. And, as is usual in such revolutions, whether in the world of active physical life or in that of mental toil, the change wrought, amidst much that was really good, not a little harm. Nor can the chronicler or historian avoid taking cognisance of the important fact, that the iconoclasm in the matter of "life-theories," amongst many other results, has tended to produce serious discord in the scientific world, and has trammelled and clogged the thought and energies of workers in other fields besides our own. The history of modern progress in biological thought and science will be found to be throughout a record of hot contention, arising chiefly from the battle of theories, and from the conflict of opposing ideas.

Treading so closely, as we do in the present case, on the confines of the "unknowable," the amount of speculation which has been indulged in respecting life-theories has loaded the biological mind with a most unprofitable burden; and we do not all possess the time, many have not the inclination or even the ability, to assume the office of scientific threshers, and riddle out the scanty grains of pure corn from amongst the mass of useless chaff which lies around us and impedes our way. To use mere hypothesis as a clue and guide to the unravelling of a perplexing and unexplained series of phenomena, is a perfectly justifiable and legitimate procedure; but, at the same time, it is one which must be very carefully distinguished from another and most unwarrantable aspect and fallacy of speculative reasoning, that of employing a mere theory as if it were based on ascertained fact; or, as if the hypothesis involved in itself facts and laws which have as yet to be ascertained, and to the knowledge of which it is the true office of speculative reasoning to lead. As has well been expressed by a distinguished thinker, "Let it not be imagined that we undervalue the assistance which science often receives from the wildest speculations, so long as these are not elaborately enunciated as *a priori* laws, but are confined to their only legitimate use, the suggestion

of new methods of interrogating nature by experiment. By all means let philosophic minds indulge in any vagaries they may choose to foster, but let these be carefully distinguished from facts established by experiment, and kept as private magazines, from which, when required, may be extracted an idea leading to an experimental research." Very necessary is it, therefore, for the student to bear in mind the caution to be careful and discriminating in all matters involving much speculative reasoning, and in no case more than in the present can the advice be strongly insisted upon.

If, in imagination, we address the query "What is life?" to an audience composed of the leaders of biological thought in our day, we should find the scientific world, so addressed, to divide itself, according to the reply given to our question, into two great sects or schools. On the one side the "vitalists" would be ranged, and the answer of this first school of thought would assume somewhat of the following character. They maintain that life or vitality is a something—call it a "force" or "principle" if we will—entirely distinct and separate from the matter through which its actions are manifested. The distinct entity of life or vital force, therefore, constitutes the chief idea in the theory of this first sect or party.

On the other side, the school of the "physicists" would be perceived, and to our question this second body would reply, that they regard life as a mere "form of energy," analogous in its operation and relations to the ordinary physical forces which operate on the world around us; and in support of this latter view, it is maintained that in the substance known as "protoplasm," the "basis," or "matter of life," has been found the necessary material in which all the properties, and indeed the source, of vital action and power may be said to reside. Life or vitality, thus viewed, is merely a property of the protoplasm, similarly as we ascribe ordinary physical properties to inorganic and inert substances.

Modifications of these chief and leading ideas will also be found to hold a place in the category of modern life-

theories; but our present aim will be most readily and satisfactorily fulfilled if we briefly examine each of these theories, together with the conclusions which may be deduced from our considerations.

And at the outset we must carefully distinguish between the significance and meaning of the terms "physical" and "vital;" since, concerning the use and application of these two words much confusion and misunderstanding have existed. By the term "vital" we mean to indicate those properties or actions which are inevitably connected with the possession of life, or which are distinctive of living beings. And by "physical" actions, properties, or forces, we mean to express those phenomena which are seen exemplified in inorganic bodies, or in the non-living matter of which the world is composed. These latter forces are manifested from without, generally with distinctly appreciable effects, and under conditions readily ascertainable by scientific inquiry. Such forces or their effects, seen in gravitation, heat, light, electricity, magnetism, etc., afford examples of ascertained "physical" forces. The force or principle, on the contrary, whereby a living organism is enabled primarily to exist, and thereafter to maintain that existence, exemplifies actions and phenomena which may be considered as essentially distinct from the preceding forces and actions, and which, therefore, we denominate "vital." These definitions simply express the leading and single significance of the terms, apart from their scientific or ultimate relations. And by thus defining them, we do not mean to imply that all the forces exerted in or through the living body are necessarily "vital," or that there is no correlation between the physical and vital forces. These latter considerations may be reserved for a later period in our studies; but it will be found of great assistance to the clear understanding of the subject, if the relative and primary significance of each term be distinctly perceived and borne in mind.

Numerous definitions of life have from time to time been framed, but, as might be expected, these merely formal expressions are limited to the enumeration or exposition

of the effects, rather than of the intimate cause or essential conditions of vitality. And from the nature of the case, in that nothing definite or certain is known of the force or principle they attempt to define, mere definitions of life or of vital force teach us little or nothing concerning the exact or primary nature of life. Indeed, several of the definitions have long ago, and on grounds we shall presently notice, been disallowed as incorrect.

Beclard, for example, defines life as "organisation in action." Duges tells us that life is the "special activity of organised bodies." Carpenter defines life as "the state of action peculiar to an organised body or organism." Bichat maintains that life is "the sum total of the forces which resist death." Treviranus held that "life is the constant uniformity of phenomena, with diversity of external influences." Lawrence informs us, that life consists "in the assemblage of all the functions or purposes of organised bodies, and in the general result of their exercise;" whilst, lastly, we may add the philosophical definition of Spencer, who reduces his ideas of vital action to the statement, that life is "the continuous adjustment of internal relations to external relations."

These definitions, as a whole, therefore deal with the effects of vitality rather than with vitality itself. Such a result will, doubtless, be considered as inevitable in the present state of our knowledge; but we cannot avoid the fact that the knowledge we do possess does not warrant us in attempting to define, or, what is much the same thing, to limit, our ideas of the vital principle.

The first three definitions are rendered useless by the consideration, that they involve the idea of *organisation* as being indissolubly connected with life, or even as being the *cause* of life. We shall hereafter have occasion to notice that exactly the opposite of this latter assertion is true,—organisation being a *result*, and not a cause, of life.

Leaving mere definitions, then, as of little or no assistance in framing a strict, or even abstract, idea of the nature of life, we may next turn our attention to the

facts upon which the respective theories of vital force are built up. Both hypotheses start with the full recognition of the differences which separate the organic from the inorganic world. They disagree only as to the nature of the cause from which these differences take origin; that cause, in the opinion of the vitalist, residing in a force or principle possessing a distinct entity from matter, and, in the opinion of the physicist, consisting in a peculiar exhibition of physical force,—a form of energy, differing only in degree and direction from other forms of energy affecting ordinary inorganic material.

Our first inquiry may appropriately be directed to the investigation of those conditions which appear more or less essential to the exhibition of vitality. Modern research has demonstrated that a common medium or substance exists, through which the phenomena of life are invariably exhibited. This "basis," or "matter of life," is therefore common to living organisms of every grade and kind. The highest plant or animal has thus a community of substance and relationship with the lowest plant or animal, in respect of this common material of which the bodies of both are composed. They differ from each other only in the degree to which development has carried out the ulterior processes of organisation, and formation of organs and parts.

The recognition of this "basis," or universal "matter of life," naturally simplified, and at the same time gave a definite starting-point, for further investigation. And the chief difference of opinion among modern theories of the nature of vitality, relates as to whether this basis or matter of life is to be considered the essential cause and origin, or merely as the result and medium for the exhibition of vital force.

It is, however, but fair to state, that some biologists are by no means disposed to agree with the statement of the universal nature claimed for the substance we have alluded to as the "basis" or "matter of life." And in this latter view it is maintained, that the "life-basis" is itself preceded by simpler forms of the living material, or

that it is by no means of uniform and universal character throughout the organic series. Still, practically, the greater weight of authority is in favour of the recognition of this common life-basis; and if we regard the term "matter of life" as including allied and nearly-related forms of living matter in its primary state, we may dispose of or modify these objections so as not essentially to interfere with the argument about to be stated.

A second consideration of importance lies in the fact that vitality very generally appears to require, as conditions for its manifestation, the presence of light, of air, of a certain temperature, of water, and in most cases, though not in all, of a greater or less degree of organisation.

Of these two great classes of conditions for the exhibition and maintenance of vitality, the first, consisting in the presence of a "life-basis," may very properly be termed an *indispensable* condition; and those just enumerated under the second head may be termed *subsidiary* conditions, inasmuch as, most, if not all, of these latter conditions may, in certain cases, be dispensed with or be absent, and yet life or vitality be manifested as if they were present. Such instances, however, are of an exceptional kind.

The presence of a life-basis, or "*materies vitæ*," constitutes therefore the indispensable condition for the exhibition of vital phenomena. This basis is found in the substance, now well known under the various names of "sarcode," "protoplasm," or "bioplasm,"—the last of these names being that which is most in accordance with strict scientific requirements. This matter of life is present wherever life or vitality is seen. It constitutes the primary or ultimate tissue or substance of which the bodies of living beings, without exception, are composed; its simple and primitive state, as already remarked, being witnessed in the lower forms of life, whilst, by a subsequent process of elaboration and development, the complicated structure of the higher organism is evolved

from this primary material. Thus the germ of the lowest plant or animal, and the germ of the highest organism of either series, are primarily and essentially the same, in respect of the protoplasm of which each is composed; and the differences which, in the after-history of either organism, are to be perceived, thus depend on the mould, and on the causes which determine the conformation of the mould, and not on the common clay or material from which both are cast.

The chemist has told us very succinctly the chemical relations of this "protoplasm." Its nature, briefly stated, is that of an albuminous substance, analogous to the albuminoid matter we familiarly see in white of egg. It belongs to a group of substances to which the term "proteine" compounds has been applied, and of this group the "bioplasm" or "life-basis" constitutes the typical example, around which the other forms of albuminous matter are classed and arranged. The exact composition of this protoplasmic material has formed subject-matter for considerable discussion; the so-called "proteine" compounds of Mulder being held to consist of an elementary substance known as "proteine," in combination with phosphorus and sulphur. There can, however, be little doubt that the typical form of protoplasmic material essentially consists of the four elements, carbon, hydrogen, oxygen, and nitrogen, united together in very high combining proportions, and after a very complicated fashion. And any further information as to the chemico-physical properties or relations of "protoplasm," may be summed up by stating, that the "proteine" compounds coagulate at a temperature of from 40° to 50° Centigrade, and that if electrical currents be sent through a protoplasmic mass, it very generally and at once contracts under this latter influence.

Protoplasm, after a merely superficial consideration of its relations, stands primarily to living beings as a conductor does to the electric fluid, or as air is related to the sounds it conveys. Life appears to require for its exhibition and manifestation this albuminous compound,

just as electricity or sound require conduction for their due manifestation. Whether or not the relation just indicated has a deeper meaning than a merely metaphorical one, will form the subject of after considerations.

Lastly, we must bear in mind the fact already insisted upon, that the term "protoplasm" is *generic* in its significance, that is, it must be viewed as including different *kinds* of albuminous matter, concerning the identity of which with the typical matter known as protoplasm, chemists and physicists are by no means agreed. And if to these considerations we add the fact, that in many instances certain forms of mineral matter, as well as other substances of alien kind, may be found associated apparently in the most fixed and intimate manner with the bioplastic material, we shall have completed all that need be said with regard to the first and indispensable condition for the manifestation of life or vital force.

It is thus of the highest importance to gain a correct idea of the nature of this protoplasmic life-basis, since the chief points of controversy in the contest between the life-theories of the present day, may safely be said to rest upon the relative interpretation of the relations which exist between the protoplasm and the vital phenomena it exhibits. Both vitalist and physicist may be held as agreeing in the universal nature of this "matter of life;" but they differ widely in their respective interpretation of the relation which protoplasm bears to vital force, or at least to the phenomena known to be perceptible in, and peculiar to living material. In the case of the vitalist this protoplasm is held to be merely the medium for the exhibition and manifestation of an entirely independent force, to which the name of "vital" force is applied; whilst in the physicist's view, the protoplasm of itself, and in virtue of physico-chemical properties and laws, originates the phenomena which he considers we wrongly denominate as "vital"—that is, as being dependent upon the assumption of a new, special, and independent force or principle.

As the chief facts and features of the physicist's theory have been succinctly stated by Professor Huxley in his address on the "Physical Basis of Life," the arguments for or against the purely physical nature of vital phenomena have generally been delivered in support of or against the views expressed in the paper just referred to. And a primary idea in the line of reasoning adopted by the physicist, consists in the assumption that because this protoplasm or universal matter of life is composed of carbonic acid, water, and ammonia—or more ultimately of carbon, hydrogen, oxygen, and nitrogen—these elements may, in logical sequence, be considered as giving origin to the phenomena of vitality which that protoplasm manifests. Life or vital action is thus assumed to arise from the union or combination of the protoplasmic elements. Or to use Huxley's own words, "carbon, hydrogen, oxygen, and nitrogen, are all lifeless bodies. Of these, carbon and oxygen unite in certain proportions, and under certain conditions, to give rise to carbonic acid: hydrogen and oxygen produce water: nitrogen and hydrogen give rise to ammonia. These new compounds, like the elementary bodies of which they are composed, are lifeless. But when they are brought together, under certain conditions they give rise to the still more complex body, protoplasm, and this protoplasm exhibits the phenomena of life."

Then we are furnished with a further and analogical example of this synthesis or building up of protoplasmic or living material. Hydrogen and oxygen unite in certain proportions to form water, and water exhibits many interesting and peculiar properties both in a liquid and in a solid state. "We call these," says Huxley, "and many other strange phenomena. the properties of the water, and we do not hesitate to believe that, in some way or another, they result from the properties of the component elements of the water. We do not assume that a something called 'aquosity' entered into and took possession of the oxide of hydrogen as soon as it was formed, and then guided the aqueous particles to their places in the facets of the

crystal, or amongst the leaflets of the hoar-frost. . . . . What justification is there, then, for the assumption of the existence in the living matter of a something which has no representative, or correlative, in the not living matter which gave rise to it? What better philosophical status has 'vitality' than 'aquosity?'"

These sentences, quoted from Huxley's address, will serve to convey, at once simply and shortly, the leading ideas in the physicist's theory of the nature and origin of vital action and phenomena. Life, according to the physicist, can thus arise *de novo.* He would expect the exhibition of vital phenomena to follow the combination of carbon, hydrogen, oxygen, and nitrogen, just as surely as water results from the union of hydrogen with oxygen. And we have therefore no more right, according to the line of reasoning thus laid down, to say that any principle, termed "vitality" or "vital force," influences the matter of life, than we have to assert that something, which might similarly be termed "aquosity," entered the water, and directed its particles to form, it may be, an ice-crystal, or the delicate tracery imitative of vegetation which appears on our windows during the winter season. Such a theory is purely "physical" in every sense of the term. Life thus reduced, is viewed simply as a property of its basis or material, and exists or appears in virtue of chemico-physical actions or laws. In other words, vitality is a mere *result*, inevitable or incidental to the formation of protoplasm.

If such be the physicist's views of the nature and origin of vital action, let us now attend shortly to the theory and views of his opponent, the vitalist. Is the instance and comparison of "vitality" with the presumed "aquosity" a strictly parallel one, and, if not, in what does the misconception lie? Or, lastly, and in connection with the preceding points, is the vitalist fully or at all justified in asserting that protoplasm is the *cause* of vitality; and is not protoplasm merely a *condition*—invariable and indispensable, it may be, but still merely a condition—under which vitality is manifested? If these points be

susceptible of proof from the vitalist's side, it is thus possible that the physicist has been confusing cause with effect, and, as a result, involving himself in much misconception and error.

So far, the point at issue concerns the view which is to be taken of the connection between life and its basis; and hence the vitalist denies that protoplasm exists as the *cause* of vitality, and views the life-basis as merely an indispensable condition or medium for the exhibition of vital force. He thus assumes the existence of a principle —the vital force—which the physicist totally ignores. The combination of elements to form protoplasm, on the part of the physicist, neither necessitates nor demands any new or independent principle; which latter, however, the vitalist maintains and upholds as the chief standpoint of his theory.

Thus the vitalist observes and knows that the body of the lower animal or plant is composed simply and entirely of a minute speck or particle of structureless, unorganised protoplasm; and, despite this barren simplicity of structure, it lives, moves, nourishes, reproduces itself, and, in short, performs all the functions of life as perfectly in its way as the highest organism. We have already seen that, in virtue of the life it possesses, it differs very materially from the inorganic things by which it is surrounded. And as it differs of itself from unorganised or lifeless objects, so also it differs from them in respect of the laws and conditions to which it is subject. It is in itself the seat of actions very different from the physical or chemical actions which affect inorganic matter from without; and we have no warrant for the assumption that any combination of purely chemical or physical forces could inaugurate, produce, or maintain, the series of phenomena we see exhibited in the humblest organism as a direct result of the possession of vitality or life.

No physicist has yet been able to produce any such combination of physical actions, nor even to hope for such a result, and, in the face of this fact, the term "vital" must be properly retained, with all the significance which

we are accustomed to regard as associated with it. The term "vital" thus stands expressive and indicative of a series of actions which fall without the boundaries of chemical or physical science, just as they exist independently of physico-chemical nomenclature.

But, apart from considerations respecting the nature of vital phenomena, the question of cause and result, or of the relations in point of *time*, between vitality and protoplasm, affords subject-matter for argument against the physicist's views. We cannot tell at what period in the history of the protoplasmic germ or animalcule it becomes possessed of life, or is "vitalised." Certain it is, that protoplasm becomes possessed of life only through the medium or influence of pre-existent life; and the question as to whether the basis or its vitality has precedence, may be debated in favour of the vitalist's views. Or, to place the question in its widest phase, we may most safely, and with least fear of being controverted, assume that vitality, self-originated or acquired, in all likelihood precedes the mass it invests; and in this view we regard the vital force as standing to protoplasm in the relation of a cause and not of a result.

It is also worthy of remark, that much confusion has arisen in discussions respecting the present subject, from the variable and widely-different senses in which the mere term "protoplasm" has been used. In many instances, no distinction is drawn between living protoplasm and dead protoplasm; and, as may readily be conceived, endless misconception has arisen from this careless and unspecific use of the term. To argue of inert, dead, or non-living albuminous material, as of living protoplasm, involves a very transparent, but at the same time a very serious, absurdity.

We may conceive it possible that the chemist in his laboratory might build up for us, by the exercise of his synthetical art, a protoplasmic compound; just, indeed, as Huxley tells us, that when the requisite compounds of carbon, hydrogen, oxygen, and nitrogen, are brought together, "they give rise to the still more complex body,

protoplasm, and this protoplasm exhibits the phenomena of life." When "brought together," the compounds of these four elements might, and probably would, produce protoplasm; but are we justified in assuming that *living* protoplasm would result from the artificial combination? It can be said, neither in the order of logic nor in the sequence of natural and reasonable phenomena, that the protoplasm of the laboratory should be living protoplasm, or that it should exhibit the simplest vital phenomena whatever. And in thus glossing over the changes and actions, be they simple or intricate, which are necessary to convert the dead albuminous matter into living protoplasm, the physicist takes an illogical leap over a wide gulf, at which a consideration of the sequence thus described compels us to draw rein. There is a very significant break in the order so narrated; and this break intervenes between the artificial formation of the dead protoplasm, and the exhibition by such artificially-formed material of truly "vital" phenomena.

Thus, then, the constructive art of the chemist might bring together the elements of protoplasm, but he would reach the utmost limit of his power with the manufacture of a dead and inert compound. We still require a something more to make the inert material exhibit the complicated phenomena, which, even in the microscopic germ or animalcule, are to be perceived, and which are thus characteristic of the truly living organism. This "something" the vitalist holds is the "vital principle" or "vital force;" a term often questioned as to its status or right of admission into scientific terminology, but which the physicist is not entitled to expunge, and for which he is unable to provide a due, equivalent, or sufficient substitute.

But further, the consideration, that in our researches we never meet with an instance capable of demonstration, of lifeless matter springing of itself into living material, affords an argument of some weight in favour of the theory of the existence of a "vital force." The dead protoplasm is always dead to us, and the conversion of

such lifeless material into living tissue can only be accomplished by the agency of an organism already living or vital. Pre-existent vitality is thus the sole and only source of vital activity and impulse, and our inability to explain the conditions under which vital force is thus transmitted does not invalidate the assumption of its existence. And granting, for the sake of argument, that it were possible to reach back through the ages of the past to those primitive germs or atoms, from which, according to the ideas of the evolutionist, all subsequent forms of life have been developed, the same question of antecedent vitality would await our consideration of these supposed primeval protoplasmic germs. It would be impossible, even in dealing with bodies of so primitive and simple a nature, to decide the question of the origin and of the circumstances of that origin, relatively to the period at which vitality manifested itself in their history.

To quote the words of M. Dumas from his "Faraday" eulogium :—"This subject remains what it was—inaccessible, closed. Life is still the continuation of life; its origin is hidden from us as well as its end. We have never witnessed the beginning of life; we have never seen how it terminates.

"Every organised being is born of a germ; every plant from a seed; every animal from an egg. The physiologist has never seen the birth of a cell, excepting by the intervention, or as the produce of a mother-cell.

"The chemist has never manufactured anything which, near or distant, was susceptible even of the appearance of life. Everything he has made in his laboratory belongs to 'brut' matter; as soon as he approaches life and organisation he is disarmed."

The parallelism between the synthetical formation of water, by bringing oxygen and hydrogen in certain proportions together, and the relations of protoplasm to vitality, is not a strict parallelism, if indeed it can be considered a parallelism at all. In the production of water after this fashion, we do not assume the existence or need of any new force. The hydrogen combines with

the oxygen to form water, in virtue of the ascertained laws of chemical affinity. But with the protoplasm, and its composition and formation, the case is widely altered, and possesses little or nothing in common with the production of water. We may manufacture our protoplasm, just as we may manufacture water. But we cannot explain *how* that protoplasm may become disposed to exhibit vital phenomena; nor can we account for or trace the origin of these phenomena, although we can with certainty and precision explain, by aid of physics, the conditions under which an ice-crystal may be formed, or an imitation forest produced upon our window-panes by the hoar-frost. We thus require and demand the existence of a new and independent force to make the inert protoplasm *live*, in the sense that even the lowest organism lives. Hence the term "vitality" cannot be set aside as an unphilosophical and incorrect expression. "Vitality," in this view, has a "philosophical status," whilst "aquosity" has no status at all.

Lastly, and by way of a final and useful thought, in judging of matters so intimately involving the distinctions between the known and "unknowable," we should bear in mind the fact, that even had we no idea of the relations of protoplasm, or had we, in point of fact, no protoplasm at all, the presumption of the existence of a "vital force" in living beings would not be lessened or affected by such a consideration. The limits and relations of the most common forces and actions, in so matter-of-fact a study as that of physics, are not always demonstrable. We do not now doubt the existence of an electrical force or a magnetic force; yet, but a few years ago, ordinary speculation as to the relations which these forces are now ascertained to possess with the external world would have been condemned, or at any rate have been subjected to criticism of a very searching kind. Yet we cannot maintain that the relations of electricity or of magnetism were the less real because of our former inability to measure or estimate them.

Or, further, if we had had no telescopes to investigate

the relations of the planets, and especially of the more obscure heavenly bodies, these relations, or the mere existence of these bodies for that matter of it, would not, on account of our ignorance, have been the less real. And so is it with "vital force." Because we cannot demonstrate its nature, origin, or actual relations, we are not entitled on that account to assume its non-existence. Just as physical forces and actions operate independently of our means for observing them, so vital force may be, and undoubtedly is, exercised, and operates, under conditions which we are unable to limit or determine. As every fact or circumstance is not at first or necessarily explicable, so also the conditions on which the circumstance depends may be insusceptible of explanation; yet it would be obviously irrational to question the fact because the explanation was not forthcoming. And in the case of the argument against the existence of a "vital force," a great amount of comment has been made on the alleged absurdity of assuming the existence of a principle, the conditions of which we cannot determine, and the relations of which we are unable to define. Let protoplasm as a life-basis and as a medium for the manifestation of vital phenomena be even removed, and vital force will still exist; just, indeed, as surely as ordinary physical forces would continue, without the media for their active conduction or exhibition.

Such may be regarded as a brief statement of the leading ideas in the respective theories which, in the present day, occupy the biological mind with reference to the nature and origin of the wondrous cycle of phenomena and actions, we collectively designate under the term "vitality," or "life." And although neither hypothesis can lay claim to having satisfactorily explained the entire circumstances and surroundings of this great biological problem, the "vitalist" theory appears to be that most worthy of support and belief. There is doubtless much that is inexplicable involved in the idea of a "vital force," but the assertion that the use of such a term is a mere cloak to our ignorance, does not bear weight when we

consider that other and professedly more rational hypotheses leave us as ignorant of the origin or nature of vital phenomena as before. If the theory of the vitalist be one insusceptible of demonstration, the hypothesis of the physicist, in spite of its matter-of-fact tendencies, tells us nothing new, since its explanation is insufficient to account for the cause and nature of even the simplest of vital actions.

Whilst thus giving countenance to the vitalist belief, we by no means wish to assert that the labours of the physicist have been of no avail or advantage. On the contrary, we cannot but feel deeply imbued with the belief, that to the labours of workers in this school of biological thought we owe many and great advances, which of late years have been made in investigations into subjects bearing intimately upon the question we have been discussing. Thus, through the efforts of vitalists and physicists in their researches into the intimate structure of the lower forms of life, we have been led to recognise the universality of protoplasm and allied substances, and from facts and information thus obtained we have been enabled to make wide generalisations, of great and useful import in the study of the life-sciences at large.

And chiefly through labours of this kind we have added largely to our stores of knowledge respecting the conditions of life in the lowest organisms. Thus, seeing this "matter of life" in its simple jelly-like state, giving origin in one case to the curious fabric of a sponge, or in another case building up the beauteous and complicated shell of a chalk animalcule; observing it taking upon its apparently simple self the onerous duties which are subserved by all the organs and tissues of the higher organism; watching it thus constituting, *per se*, a living being, able perfectly to nourish itself, reproduce itself, and to maintain all the relations which ordinarily exist between the living organism and the sphere it inhabits—observing these multifarious duties devolving upon, and performed by a medium so simple and structureless, we may well stand amazed at, and puzzled to account for,

the origin and exhibition of such wondrously complicated powers.

Whilst thus we are forced to admit our ignorance of the origin of such phenomena, we yet find in the theory of a "vital force" possessing an entity distinct from matter, as satisfactory a hypothesis as in the present order of things we are entitled to expect or believe. What life in its essential part is, we therefore do not know, nor may we with assurance predict that the higher knowledge of the future will render the problem of living and being any the less mysterious or inexplicable. We can make no limitation to scientific inquiry. We cannot wish to bind or curb the tendency of that freedom and energy of thought which has already accomplished so much for the good of mankind at large. But, at the same time, we cannot understand how we shall readily arrive at a knowledge of what appears to be within the confines of the unknowable, and of what, from its very nature, must fall beyond our utmost ken.

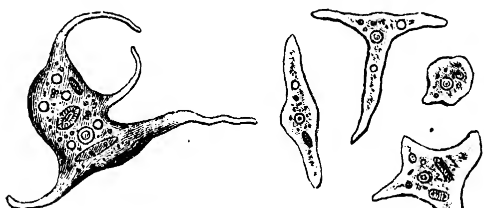
In concluding the considerations relating to the nature of life and vitality, we have to notice, very briefly, the second set of conditions which we have already observed to be more or less essential to vital manifestation. The presence of protoplasm, or of a distinct "life-basis," forms, as we have seen, the first and indispensable condition for vitality. The second set of conditions, to which we may now direct attention, are termed *subsidiary* conditions, since part or all of these latter may be suppressed, and yet vitality be perfectly exhibited and maintained in their absence. Regarding the merits and place of most of these subsidiary conditions, biologists are very generally agreed, although much yet remains to be ascertained regarding the various and modifying circumstances which affect the stability of these latter conditions of life.

The presence of a greater or less degree of *Organisation*, may appropriately form the first consideration to which attention may be directed. The relations of organisation to vitality have been, and indeed still are, subject to much misconception. We have already noticed that not

a few definitions of life hinge upon the recognition of organisation as a *cause* of life. Such expressions as "the special activity of organised bodies," and "organisation in action," assert a belief in the constant and invariable presence of organised structures, tissues, or parts, as necessary for, and indeed as a cause of, the manifestation of vital action.

By organisation we mean—as indeed the mere significance of the term would imply—the possession by a living being of definite structural parts or organs, bearing distinct and fixed relations to each other. Most animals and plants are "organised" in this sense of the word, but at the same time it is to be borne in mind, that there are very many lower forms in both kingdoms, which, if the above definitions of life were held as true, would fall without the pale of the organic or living series. In other words, we have animals and plants existing and living, without being in the least degree organised.

The *Amœba* (Fig. 1, *a b*), found in stagnant water, or any one of the *Foraminifera* or their allies (Fig. 2, *a b c*),



a *b*

Fig. 1. RHIZOPODA.

a, *Amœba radiosa*, showing pseudopodia, contractile vesicles, nucleus, and food-vacuoles; *b*, *Amœba diffluens* in various stages of contraction.

exemplify animal forms in which few or no traces of organisation are to be perceived. These organisms are closely related to each other, the bodies of both consisting of minute masses of granular sarcode or protoplasm, which to all intents and purposes is void of any definite structure, and consequently destitute of anything meriting the name of

organisation. Yet each little particle of sarcode constitutes a perfect being. It lives, moves, grows, and reproduces itself, and, as in the case of the *Foraminifera* (Fig. 2), may even manufacture shells of exquisite beauty and design.

Hence the immeasurable difference and distinction between the broad comparison of a piece of mechanism, such as a watch, and a living being or organism. The various parts or "organs" of the watch possess each a distinct relation to one another; just, indeed, as the organs of the higher animal or plant exist in definite combination to perform all the functions of life. But if we extend the comparison to include all animals and plants, the parallelism between the mechanical and the vital organisation at once fails. In the humble, structureless animalcule, the functions of life are carried on without any distinctive organs or parts to perform the work. The essential feature of the watch—complex mechanism—is exactly what is wanting in the *Amœba* and allied forms.

A disregard of this consideration has therefore resulted in the pushing of the common analogy between animals and pieces of mechanism a degree too far; one consequence of this disregard being the institution of the dogma that life is dependent on organisation. The reverse, therefore, is really the case. The living body is organised because it lives; but, at the same time, it may exist and live without exhibiting the faintest traces of organisation. Organisation, where it occurs, is merely a *result* and not a *cause* of life.

The presence of *Air* is generally regarded as a very constant subsidiary condition for vital activity. Perhaps this fact would be more correctly stated by asserting that certain *gases* appear necessary and generally essential to the maintenance or exhibition of vital action. Oxyg gas is thus regarded as needful for the due mainten of animal existence, whilst carbonic acid gas is esse to the life of the plant. Certain exceptions to general rules occur in the case of many of the lower bers of both kingdoms; some of the lower plants

capable of existing in an atmosphere of oxygen, whilst some *Protozoan* forms appear to flourish amid carbonic acid gas. These latter facts will, however, be more fully and appropriately noticed when we consider the relations of the animal and plant worlds.

A certain degree of *Temperature* is also looked upon as usually necessary for the maintenance and exhibition of vitality; but throughout both animal and plant kingdoms the variations in the degree of heat and cold suited to the existence of the contained organisms are so numerous and marked, that it is almost impossible to pronounce

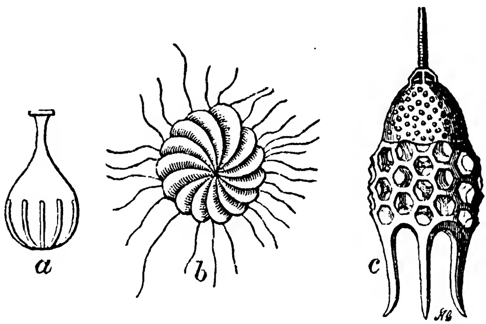


Fig. 2. FORAMINIFERA AND RADIOLARIA.

a, *Lagena striata*, a monothalamous or sing
Polystomella crispa, with pseudopodia e
apertures in the shell; *c*, *Podocyrtis Schomburgkii*, a *Radiolarian* form.

definitely on this head. The limits of ordinary vitality are said to exist between freezing point and about 130° Fahrenheit; but we are well aware that a temperature far below the former, and also much above the latter, does not necessarily or at all interfere with the development of life in lower organisms.

The effect of *Light* in the manifestation of vitality is to be regarded as of considerable importance, although, like the preceding condition, it does not appear to be absolutely or invariably necessary that the living organism should be

exposed to its influence. As regards the plant creation, light is certainly the great agent by which the subtle chemistry of vegetation, to be afterwards noticed, is set in operation and carried on; but we have also to bear in mind that, as before, the lower groups of plants and animals present instances of exceptions to this rule. Not a few animals occupying a high place in the created scale live and grow in the dark; these cases, however, generally exhibiting that want of colour, and other abnormal or unusual conditions, which appear to result from non-exposure to the influence of sunlight.

The *Foraminifera* and their allies (Fig. 2), forming vast fields of life in the greatest depths of the sea, are placed in the position of animals far removed from the influences of the solar beam; and amongst the latest discoveries which deep-sea dredging expeditions have brought to light are certain higher forms of animal life, provided with eyes of the ordinary type of structure, and which would seem to pass their lives in an altogether abnormal state. This subject will be hereafter referred to, but the entire question is one of considerable difficulty and complication.

In *Water* we find an intrinsic and intimately-associated condition for vitality. Water enters into the composition of every living organism; a fact not strange or new to us when we recollect the composition of protoplasm itself. Accordingly, wherever we find the "matter of life," we have a certain proportion of water present as a component and constant part of the protoplasm.

Viewed apart from this consideration, however, we generally find that water bears a close and most important relation to the vital processes, and, as a consequence, to the mere exhibition of vitality also. Yet, as before, vitality may exist without the presence of water, although, as will be presently explained, the conditions of such vitality are of an abnormal and unusual kind.

The consideration of life-theories, and of the concomitant questions which are naturally related to such a subject, would be incomplete if we did not notice the use

and significance of the term "death," and also the occurrence of certain conditions included under the general term of "altered" vitality.

By the "death" of an organism, we mean the cessation of vital activity, and the consequent suspension of the processes and actions which the living body, in virtue of its vitality, evinces and exhibits. A period this, in its existence, marked by its surrender to those physical and chemical forces, which the possession of vitality enabled it to avail itself of or to resist. The dead protoplasm, that is, protoplasm *minus* vital force, is thus subject to the same actions that affect ordinary inorganic or non-living material. The living protoplasm, in virtue of its life, is lifted, as it were, above inorganised matter, and endowed with all those characteristics which we have observed to mark the presence of vitality.

The term "altered" or "potential" vitality refers to certain conditions, under which the active exhibition of vital force may, for a longer or shorter period, be suspended. This condition is typically seen in the seeds of plants, which may be kept for centuries in a dry and parched condition, and which, on being placed in the soil, at once revive and give origin to their usual forms of plant structure. The vitality in such a case is throughout inherent in the seed, and appears to be in a condition analogous to that seen in a half-drowned person, whose animation or vitality is said to be "suspended." Such vitality, therefore, we term "dormant," "potential," or "altered," and numerous examples of this condition occur in both the animal and vegetable worlds.

The *Rotifera* or "wheel animalcules" (Fig. 3, A B), tiny and microscopic inhabitants of all our pools, may be dried up or desiccated from the water by the heat of the sun, and be blown about by the wind as mere dust-specks. In this mummified condition they may exist even for years, yet upon the addition of a little moisture they resume all the functions of life with renewed vigour.

And such a statement is to be regarded as the more

wondrous, when we consider that the *Rotifera* are creatures of very complicated organisation (Fig. 3).

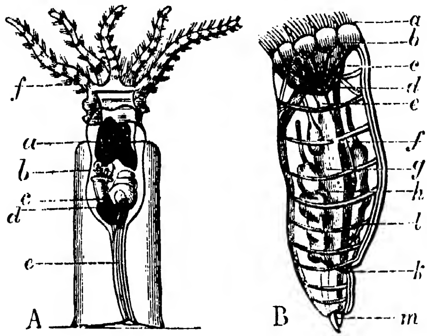


Fig. 3. ROTIFERA.

A, *Stephanoceros Eichornii* (greatly magnified): *a*, pharynx; *b*, gizzard; *c*, stomach; *d*, ovary; *e*, foot; *f*, tentacles. B, Anatomy of *Hydatina senta* (female) (magnified): *a*, cilia; *b*, ciliated discs; *c*, muscles of jaws; *d*, nervous ganglia; *e*, gullet; *f*, salivary gland; *g*, stomach; *h*, ovary; *k*, anus; *l*, vascular system; *m*, terminal appendages.

We must, however, carefully distinguish between the terms "revive" and "revitalise." Much confusion has existed from the indiscriminate use of these terms, and a clear idea of their true meaning and significance cannot be better conveyed than by the words of Dr. Lionel Beale, who says—"To revive and revitalise are two very different things. That which is not dead may be revived, but a thing that is dead cannot be revitalised. The animalcule that can be revived has never been dead. The half-drowned man who revives has never died. The difference between the living state and the dead state is absolute, not relative. The matter from which life has once departed cannot be made to live again."

CHAPTER III.

Distinctions between the Animal and Plant series—Difficult nature of the Subject—"Regnum Protisticum"—Comparison of Animal and Plant forms with reference to Form; Motor Power; Chemical Composition; Intimate Structure; Nature and Mode of Assimilation of the Food—Relations of the Animal and Plant worlds.

THE relations which exist between organic and inorganic bodies having been already discussed, we then observed how sharply and definitely things living were separated from things lifeless. The inanimate crystal possessed no relations in common with the animal on the one hand, or with the plant on the other. We now proceed to the consideration of a second set of differences—namely, those which exist between the two great groups or series of living beings, animals and plants.

And to the unscientific observer our present task might appear to be followed by results quite as certain and definite as those which were elicited from a consideration of the differences between the organised and inorganised series. Nay, so patent, so obvious, and so apparently well ascertained are the differences between the animal and plant worlds, and between their contained organisms, that the task of enumerating any supposed distinctions or boundary-lines of either group may at first sight appear wholly unnecessary. "What relations, connection, or similitude," one might ask, "is there between a horse and the herbage it crops; or between a bird and the tree amid the foliage of which it builds its nest?" And to such a query we might at first be disposed to reply, that the only relation perceptible between these organisms exists in the possession of a common vitality. Both are organic or alive; but, to the unscientific mind, all resemblance would cease at this stage of comparison.

The difficulty, however, lies not so much in the expression of mere relations, or in embodying relative ideas of the animal or plant, as in the construction of a strict and absolute definition or idea of either. In the latter attempt, the ordinary modes of distinction between animals and plants are seen signally to fail. Nor does the difficulty which besets our task lie so much, or at all, with the higher forms of either series, as with the relations of the kingdoms as a whole. For if we leave the higher members of either kingdom, and descend to the contemplation and comparison of the lowest animal and plant organisms, we shall then arrive at some conception of the arduous and unsatisfactory nature of the task before us. On comparing the *Protozoa*, or most lowly organised animals, with the *Protophyta*, or lowest plants, we find that most, if not all the points of distinction, which in the case of the horse and the grass appear so certain and determinable, utterly fail us in the separation of many of these lower forms of life. Yet the *Protozoa* are to be regarded as no less true animal forms than are the *Vertebrata*; nor are many of the *Protophyta* less typical plant-forms than their higher neighbours. Consequently, if our definition or idea of an animal or of a plant is to be of any utility, it must of necessity be universal in its application, and must serve to include all organisms which belong to either life-series. Hence we must take cognisance of the lower as well as of the higher forms, and it is in the consideration of the former group, in both kingdoms, that we experience our greatest difficulty.

Nor has the unsatisfactory nature of our present subject been made apparent of late years only; or in the more philosophical eras of biological thought. We may discover in the records of the older naturalists an enumeration of many organisms, which, on the grounds of form, mode of life, or the possession or want of locomotive power, they could not definitely or satisfactorily place in one kingdom or in the other. Sponges, for example, have formed a kind of *bête noire* to the naturalist in this respect; and even in the present day there are some

authorities who, in defiance of generally accepted views, and on grounds of philosophical and scientific nature, would seek to support the views of the ancients, and regard sponge as essentially a vegetable organism. And when we further reflect that up to the beginning of the eighteenth century the *vegetable* nature of red coral had not been disputed, it will readily be understood how little had been done in the way of ascertaining the exact limits and characteristics of either group of organisms.

Even in this advanced era of scientific progress, and in these days of ascertained facts and observation, together with the advantages of extended opportunities and means of research, the almost hopeless nature of accurately and absolutely defining and limiting the animal and vegetable kingdoms, has induced some biologists to suggest the formation of a third or intermediate kingdom, for the reception of organisms, concerning the nature of which there is reason to entertain any doubt. Of this description of " biological No man's land,"—as Huxley terms this intermediate series—the " Regnum Protisticum " of Hæckel may be selected as a typical example. And biologists, following the example and tenets of this distinguished naturalist, would accordingly place in this debatable territory a good many of the *Protozoa*, and not a few *Protophyta*, which by other authorities would simply be included in either animal or plant series. The views of Hæckel have not met with any very general acceptation from biologists at large. Year by year we are led the more hopefully to entertain the belief that the distinction and differentiation of the two great life-series, or at any rate the exact and intimate relations of both, will be demonstrated. And hence we are justified in declining to avail ourselves of this biological make-shift, the recognition of which is nearly tantamount to admitting at once the hopelessness of the task, and the futility of further research. Professor Huxley well expresses himself with regard to this matter, when he declares that the recognition of a " Regnum Protisticum " " merely doubles the difficulty which, before, was single."

At the same time, we must candidly admit and face the difficulty, such as it is. And in the present state of our knowledge the relations of the animal and vegetable kingdoms may be aptly diagrammatised by drawing two circles which shall touch one another at a point in the circumference of each; in other words, at this point the circles will merge into each other. This point, in the case before us, is the neutral ground where the *Protozoa* and *Protophyta* meet; and with the last remark that our diagram of the circles expresses the relations of the animal and plant worlds, conditionally, and relatively to the future progress of scientific inquiry, we may close these purely introductory considerations.

We may compare animal and plant forms, with a view to the determination of their relations, according to five points. These points are:—(1.) *Form*; (2.) *Motor Power*; (3.) *Chemical Composition*; (4.) *Intimate Structure*; and (5.) *The Nature and Mode of Assimilation of the Food*. On the first four of these heads we shall have occasion to notice how the ordinary modes of drawing distinctions between animals and plants fail; and similarly, on the fifth and last point we shall observe that this latter head—the "Nature and Mode of Assimilation of the Food"—affords the only warrantable basis on which we may found lines of demarcation between the animal and plant series.

Firstly, then, we may notice how the *Form*, or external characteristics of animals and plants are inadequate for the purposes of distinguishing between them. Obvious enough as this distinction may seem from a popular point of view, and when applied to the higher groups of the series, there are yet many animal forms, of comparatively high structure and organisation, which, on this ground alone, could not be distinguished from, but on the other hand would most certainly be confounded with plants.

Examples of such plant-like animal-organisms—are depicted in the accompanying illustrations. A large group of animal forms, known as the *Hydrozoa*, or *Hydroid* Zoophytes or Polypes (Fig. 4, *a b c d*), exemplify how

deceptive a distinction mere form or external configuration constitutes. In this case we observe a structure essentially plant-like in its conformation and in all its details (Fig. 4, *a c*). It grows from a fixed point, and further shows its external relations with the vegetable world in that it reproduces itself by a process of "gemmation"

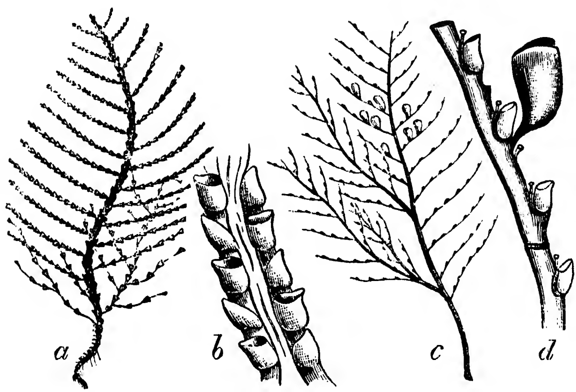


Fig. 4. HYDROZOA (after Hincks).

a, Portion of the "hydrosoma," or entire organism of *Sertularia fusca*, one of the "Sea Firs" (a little larger than natural size); *b*, part of a branch of *a*, greatly magnified, showing the horny cups or "hydrothecæ," in which the "zoöids" or polypites are contained; *c*, "hydrosoma" of *Plumularia frutescens* (natural size), with reproductive capsules; *d*, portion of a pinna or branch of *c* (greatly magnified), showing the cells of the "zoöids" and a reproductive capsule.

or "budding." Yet a microscopic examination of the *Hydrozöon* at once shows us that the tree-like structure is undoubtedly an animal organism, but of compound nature; and we can readily observe the little semi-independent "polypites" or factors (Fig. 4, *b d*) of which the colony, or compound organism, is made up.

Then, also, we notice the well-known Coral-polypes—of historical interest—as being long mistaken for plants, until the observations of Jean Peysonnel demonstrated their truly animal nature. A piece of Red Coral in its

living state, with its living bark, containing the little organisms or "polypes," expanding and contracting their tentacles, like so many flowers, is by no means a bad imitation of a vegetable organism in full growth.

Amongst the *Protozoa*, and particularly in the case of the *Infusorial* animalcules—so called from their being found in infusions of animal or vegetable matter—we find many organisms which are continually being confounded with and mistaken for the embryonic forms of the lower plants. The ciliated "zoospores," or germs of many *Algæ*

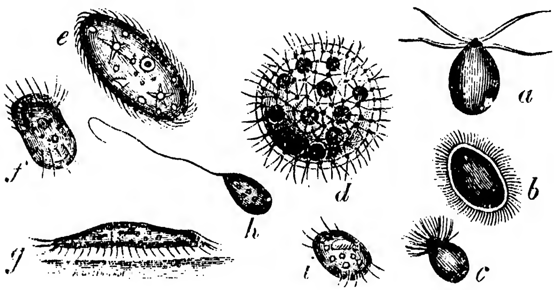


Fig. 5. INFUSORIA AND ALGÆ.

a, Zoospore or locomotive germ of a lower or *Confervoid* plant (*Chætophora*), with four vibratile cilia; *b*, zoospore of lower plant (*Vaucheria*), with numerous cilia; *c*, zoospore of *Conferva*, with tuft of cilia; *d*, *Volvox globator*, one of the lower *Algæ* in its adult state, long considered of animal nature: *e*, *Paramæcium aurelia*, a true *Infusorian* animalcule: *f*, *Euplotes Charon*, an *Infusorian*; *g*, *Oxytricha gibba*, one of the *Infusoria*; *h*, *Peranema globulosa*; and *i*, *Aspidisca lynceus*, two *Infusorian* animalcules (all greatly magnified).

or Sea-weeds (Fig. 5, *a b c*), are in many cases not to be readily distinguished from certain *Infusoria* (Fig. 5, *e f g h i*); these little plant germs exactly resembling their animal neighbours in all the outward details of existence.

In the *Volvox globator* (Fig. 5, *d*), an organism commonly found with *Infusoria* and other forms in stagnant water, and which is familiar to every microscopist, we find a typical example of how nearly in form even an

adult plant may approach to an *Infusorian* animalcule. To see this organism rolling over and over upon itself, propelled through the water by means of the circle of "cilia" or eyelash-like filaments which fringe the margin of its body, would at once tend to make the uninitiated observer believe he was looking upon an undoubted *Infusorian* form. Yet its truly vegetable nature has now been placed beyond a doubt. And, as ranking amongst the *Protozoa*, a sponge, in so far at least as mere external appearance is concerned, might more readily be assigned to the vegetable than to the animal creation.

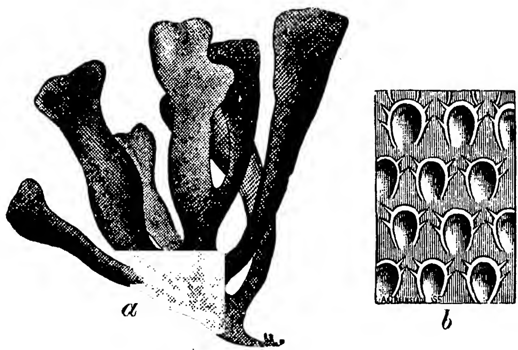


Fig. 6. MORPHOLOGY OF FLUSTRA, OR "SEA-MAT."

a, Cœnœcium or entire organism of the "Broad Hornwrack" or "Leafy Sea-mat" (*Flustra foliacea*), natural size; *b*, a few cells of the same, greatly magnified.

But, lastly, and even more typically than in the preceding cases, the resemblance of an animal organism to a plant-form is seen in the *Flustræ*, or "Sea-mats" (Fig. 6, *a*). These organisms must be familiar to every sea-side visitor as forming part of the chaotic mass cast up on the shore by the tide, and to which the very characteristic and appropriate term, "rejectamenta," has been applied. The illustration will serve to convey an idea of the appearance of a familiar species, from an inspection of

which the essential features of the organism will be readily apparent.

We firstly notice its essentially plant-like form—so plant-like, indeed, that it is commonly collected by seaside visitors as a seaweed, and, as such, frequently occupies a prominent position in seaweed herbaria. Nor can we altogether afford to ridicule the mistake, since its resemblance to seaweed is so close, that it requires some previous knowledge to separate "the sea-mats" from the heterogeneous mass of marine vegetation with which they are generally cast upon the beach. Or, if we saw the *Flustra* in its normal and living state, as it grows attached to stones and shells, and as we obtain it from the dredge, its resemblance to a seaweed would appear even more realistic than before.

But notwithstanding this strange similitude to a plant form, we can, by a very simple and superficial examination, demonstrate its truly animal nature. If we scrutinise its surface with the naked eye, or, better still, by aid of a pocket-lens, we can observe the external division of the plant-like surface into numerous little cells or spaces, which, greatly magnified, exhibit the appearance depicted at *b*, Fig. 6. And the observation of the *Flustra* in its living state would show that each little cell was occupied by a tiny inhabitant, the head of which, surmounted by a corona or crown of tentacles, would be continually waving backwards and forwards in the surrounding water. And a more minute examination would reveal, contained within the cell, a simple but characteristically animal organisation (Fig. 9), which will be noticed at a subsequent stage in our studies. Each little cell of the "sea-mat," and its contained inhabitant, is the exact prototype of its neighbours, and of such cells the entire organism is made up. It is, therefore, like the *Hydroid* zoophyte, a "compound" organism; it reproduces itself after plant-like fashion, and as a result developes an organism in the similitude of a plant.

Thus not only is the *Flustra* of undoubted animal nature, but it also occupies a very definite and by no means lowly

place in the animal world. For when we consider that it belongs to the great division of the animal kingdom known as the *Mollusca*, and that in this division are included all our ordinary shell-fish (oysters, mussels, cockles, whelks, etc.), as well as those higher forms known as cuttlefishes, it will be seen that the "sea-mat," so far from being an animal of humble organisation, ranks comparatively high in the created scale.

The consideration of these and other examples, which but a very slight acquaintance with systematic zoology will readily afford, may serve to demonstrate that, under the head of *Form*, we cannot distinguish between the animal and plant series.

A sufficiently popular and obvious distinction between the animal and plant series would appear to consist in the possession by animals of *Locomotive* or *Motor power*, and in the opposite and generally fixed condition of plants. Let us briefly inquire whether this second mode of distinction be more trustworthy or reliable than the previous one.

Do all animals move about? are they all possessed of motor power? And conversely, are all plants fixed and rooted to the soil, and so destitute of locomotive means? A little consideration will at once suffice to enable us to answer both queries in the negative, and so to dispute the validity or correctness of this second distinctive point. Look at the sponges, the coral-polypes, the hydroid zoophytes, the sea-mats, the sea-squirts, and many other animal forms which are entirely destitute of locomotive means, and which spend their lives in a permanently-rooted and fixed condition. Or, on the other hand, witness the free and locomotive habits of many aquatic plants, which serve to disprove the assertion that vegetable existence is necessarily of a fixed description.

The locomotive spores and germs of many aquatic plants (Fig. 5, *a b c*), or other and adult *Protophyta*—such as *Volvox* (Fig. 5, *d*), *Diatomaceæ*, etc.—which are never fixed and rooted at any period of their life, but live an entirely free and independent existence, exemplify

typical cases, in which the presence or absence of *motor power* is shown to be no safe or reliable criterion of the exact nature of any disputed organism.

Whilst, therefore, in the abstract, or in a general sense, the power of locomotion may be considered as distinctive of the animal organism, it is also to be noted that the special value of the present mode of distinction does not rank any higher than that of *Form;* and this latter point we have already seen to be of no service in defining for us the relations of the two kingdoms.

Thirdly, it may be asked, Can the chemist, under the head of *Chemical Composition*, aid us in the task of framing distinctive points between the animal and vegetable creation? To this query, also, a negative reply must be returned. Indeed, so far from assisting us in our labour, the chemist's evidence but renders the task still more hopeless and confusing.

His statements, relative to the intimate or elementary composition of animals and plants, show that carbon and its compounds form the chief elements of importance found in the analysis of plant tissues; whilst nitrogen and its compounds may be said to hold a similarly prominent place in the composition of animal textures.

More intimate inquiry, however, will show us that this statement is only of abstract and indefinite value; and that chemical composition—in so far at least as relates to the discovery or recognition of certain elements as specially distinctive of plants on the one hand or of animals on the other—can afford us no certain means of diagnosis between the nature of the plant and that of the animal. Many elements and compounds are common to both plants and animals, and conversely, no one element or compound can be said to be specially characteristic of or peculiar to either series.

But the chemist's evidence does not end with this very general statement. Another aspect of the subject tends to prove that his testimony will go very far to weaken the case for the distinctive character and value of this third

head. He may further inform us that certain substances long thought to be peculiar to vegetable organisation have now been detected entering largely into the composition of animal textures; and in this view the chemical analysis of a living being cannot be said to at all aid us in founding distinctive characters of its nature. Thus "cellulose," a substance entering largely into the composition of vegetable tissues, and of which woody fibre and the walls of plant-cells are chiefly composed, has now been ascertained to form the greater part of the outer covering of *Ascidians* or "Sea-squirts"—*Molluscous* animals allied in a manner to our ordinary shell-fish. The fact of so characteristic a vegetable product being found thus intimately associated with animal structure, was, to use Huxley's expression, "justly regarded as one of the most remarkable facts of comparative physiology."

In the case of "chlorophyll," or the green colouring-matter of plants, a similar result has been found. This latter and characteristic vegetable product is observed to impart the green colour seen in many *Infusoria*, in the *Hydra* or "fresh-water polype" (Fig. 7), and in many other animal forms. Neither cellulose nor chlorophyll, in themselves sufficiently well-marked vegetable products, can therefore be said to be characteristic of the plant creation.

And chemistry furnishes us with many similar but less familiar examples of this seeming interchange of products. The liver and placenta of most *Mammalia* are known to manufacture or secrete, among other products, a substance known as "glycogen" or "animal starch," and this latter substance appears to be of nearly similar composition to the starch obtained from and elaborated by plants.

Such examples, therefore, tend to show that, for our present purpose of distinction, chemical science can afford us no more definite or reliable aid than form or motor power.

Fourthly, we may inquire whether the microscopist can render us any better assistance than the chemist? Will the microscope enable us to detect in the *Intimate structure*

of animals and plants any perceptible and decided difference between the two groups or series?

If we microscopically examine the tissues of a plant, we find them to consist of certain elementary bodies known as "cells" and "vessels;" or if we called development to our aid, we should find that the primary form of plant structure would be referable to the "cell" itself—the "cell" consisting of a more or less rounded structure, generally of small or microscopic size, and composed of a cell-wall, cell-contents, and a little contained particle, the cell-centre or "nucleus" (Fig. 19). Or, if we sought to trace development prior to the formation of the cell, we should find that elementary constituent of plant structure to be in turn formed from a uniform life-basis or bioplastic mass, or from the aggregation of organic particles known as "molecules."

Turning now to the investigation of animal textures, the microscopist finds that the tissues of the animal are built up of elements similar in kind to those he observed in the intimate structure of the plant. Bone, muscle, tendon, nerve, skin, and every other tissue found in the economy of the animal, is composed of certain definite cell-structures, which, under the microscope, are capable of being readily and certainly recognised. And in the progress of animal development, the process, as observed anterior to the formation of the cell-structures, is essentially the same in kind as that seen in the production of the plant-form.

The science of "Histology," or that which investigates the minute structure of bodies and tissues, both in itself, and from its bearings on the developmental process, thus reveals a striking identity in form and composition. The difference between the intimate structure of plants and animals is therefore one of degree only; variations in form, composition, or texture, having no effect in modifying the typical plan upon which the elements of the animal or vegetable body are built up and arranged.

The Nature and Mode of Assimilation of the Food, constituting the fifth and last head, forms, as we have previously

remarked, the only sure and definite ground on which we may separate the animal from the plant world. And this latter point has therefore reference to the distinctive characters to be drawn, firstly, from the *kind* of nutritive material necessary for the maintenance of animal and plant organisms respectively; and, secondly, from the *nature of the process* by which such nutrient matter or food is elaborated and rendered fit for the due support of animal and of plant life. And if, to these primary considerations, we add those relating to the *results* of the conversion and assimilation of the food, in each case, we shall find the distinctions deducible from our considerations to be of a very definite and satisfactory kind.

The *nature* of the food of the animal differs essentially from that of the food of the plant. Animals require for their due sustenance *organic* material—that is, matter which has been derived from the bodies of living organisms, and which has therefore been already elaborated. Plants, on the other hand, subsist on *inorganic* material, or upon matter devoid of life, and derived simply, and without previous preparation or elaboration, from the external world.

Primarily, therefore, the nature of the food, thus briefly stated, shows a very important source of distinction between animals and plants. Beginning in a natural order with the nutrient interests of the plant, we find the vegetable world subsisting on the three great compounds which we have previously noticed to unite in the formation of the "matter of life," or "protoplasm." These compounds are water, carbonic acid, and ammonia; and if to these we add the very general presence of certain mineral salts, such as the compounds of lime, soda, potash, flint, etc., we shall have completed the very modest bill of fare which the plant requires for its nourishment and growth.

Such being the nature of vegetable food, what are the results of its assimilation within the plant organism? Roughly stated, these results are evinced in the production and manufacture by the plant, in virtue of its

characteristic and inherent vitality, of the proteine or protoplasmic compounds. The vital chemistry of the plant, in other words, converts the inorganic material into organic or living matter; living protoplasm is thus produced, as we have previously remarked, only by the intervention and operation of an already living organism. And the plant, in the exercise of its vital functions, therefore, converts compounds of simple and inorganic nature into organic and highly complex compounds.

In the consideration of the nutritive process in the animal economy we are met by a result totally different, and as nearly as possible opposite to that seen in the plant. The animal requires for its sustenance, as already remarked, organised or living material. This term is synonymous with matter that has undergone elaboration by the vital chemistry of a living being, and for this material the animal is dependent, primarily, upon the plant creation. It obtains the organic matter necessary for its sustenance from the plant world, and in this view plants therefore form the great bulk of animal food. But with the reception into its body of this organic nutritive material, a series of actions widely different in result from those seen in the plant economy, are now to be noticed in the assimilative process of the animal. The vital chemistry of the animal has a direction and operation entirely different from that of the plant. The complex compounds formed by the plant, and offered as food to the animal, are, in the animal economy, reduced to much simpler and less complex bodies, and these latter are finally inorganic in character. The carbon contained in the food of the animal in this way is returned to the atmosphere as carbonic acid, the nitrogen is got rid of chiefly in the form of "urea," whilst the hydrogen of the organic compounds derived from the plant, reappears in an inorganic form, and in greater part as water. Thus the waste products of the nutritive process in animals are essentially inorganic in nature, and result from the absorption, assimilation, and elaboration, of organic nutritive material.

The animal thus lives on organised material; the plant

subsists on inorganic matter. The animal converts such organic material, consisting of highly complex compounds, into inorganic and simple compounds. The plant converts the inorganic matter, consisting of simple compounds, into organised matter, and into highly complex compounds. The stable elements, or compounds of inorganic substances, are, by the plant, converted into highly unstable compounds of organic nature, and which serve the animal for food. The whole course of plant life is a process of reduction, deoxidation, unburning, and of building up organised material. The whole course of animal existence is a process of oxidation, burning, or breaking-down of organised matter as the result of tissue-waste, into inorganic or non-living material. The plant constantly produces, and the animal as continually consumes.

Several other points, of subsidiary importance to the preceding considerations, may appropriately be noticed at the present stage. Thus the food of animals is generally *solid* in its nature, whilst that of plants is usually liquid or gaseous; this latter rule being of very constant nature, in so far at least as plants are concerned.

An important and further ground of distinction between the animal and plant worlds, and one which is closely related to the nature of the food, is found in the respective effects or reactions of animals and plants upon the atmosphere. This latter point has reference to the gaseous interchange which takes place between the animal and plant kingdoms, and which affords an apt illustration of the great law prohibiting waste and mismanagement, which Nature seems to inculcate and exemplify throughout all her dominions, and in all her operations.

The animal requires for the due performance of its vital functions a certain amount of oxygen gas, which it derives from the atmosphere by which it is surrounded. This oxygen is therefore absorbed by the animal, which in turn excretes or gives out to the atmosphere, as the part-result of its tissue-waste, a certain proportion of another gas known as carbonic acid. This latter gas is exceedingly deleterious to animal life, but plants, on the

other hand, absorb and inhale the carbonic acid, which is to them what oxygen is to the animal; and we have already noticed how the carbonic acid is elaborated by the subtle chemistry of the plant, to aid in forming the protoplasmic compounds so necessary for the support of animal life.

The plant, in the exercise of its vital chemistry, next retains to itself the carbon, and sets free the oxygen, which also forms part of the carbonic acid. The free oxygen is thus returned by the plant to the atmosphere, to be again made subservient to the life and functions of the animal. The chemist represents carbonic acid by the symbol CO_2, signifying that Carbon (C), and Oxygen (O), combine in certain proportions to form carbonic acid; and we may roughly diagrammatise the action of the plant, if we suppose it to retain for its own use the C, and to allow the O_2 to return to the atmosphere. The animal thus absorbs what the plant excretes (oxygen); and the plant absorbs what the animal excretes (carbonic acid). In this way, therefore, those substances which we might consider to be the waste and useless products of one economy, are, in virtue of nature's wise plan, utilised and made subservient to the welfare and nutrition of the other.

The *mode* in which the food is assimilated in animals and plants respectively, forms the second division of our present subject. This latter consideration essentially assumes the nature of a comparison between the nutritive organs of plants and of animals. Broadly stated, the nutritive and absorbent organs of plants are *external*, that is, are situated on the outer surfaces of the organism. Conversely, in the animal, the nutritive organs are *internal*, and we generally find that a distinct cavity or tract is apportioned off from the internal surfaces of the body to subserve the digestive or nutritive function.

Even in the lowest animal organisms (*e.g.* the *Amœba*, Fig. 1), in which a true and distinct digestive cavity or stomach is not specialised from the general protoplasm of which the body is composed, we find that a temporary

internal digestive cavity is formed as occasion requires, and food by this means is received into the interior of the organism. Thus, in an *animal* form of nearly ,the lowest grade of organisation, the generalisation concerning the relative position of the nutritive organs in the animal and plant series still maintains its validity.

The primary process of nutrition in plants is subserved by the root and leaves, the absorbed materials being exposed to the action of the sunlight chiefly through the medium of the latter organs. In plants, however, we find an internal system of cells and vessels, to which a circulatory function may be correctly assigned; this latter system distributing throughout the organism the elaborated products of the nutritive process. Such a system bears a close and undoubted analogy to the circulatory system of animal forms; but the primary processes of nutrition are subserved in the plant by external organs, whilst in the animal we find the food directly received into the interior of the body.

The presence of a distinct mouth or oral aperture for the reception of food, is by no means a constant or unvarying characteristic of the animal series. The lower forms of animal life, in common with their want of organisation and the non-possession of distinct structures and parts, are generally destitute of a special aperture for the reception of nutrient matter, and in some forms of comparatively high structure, a distinct mouth, and, in some cases, even a distinct digestive system, are also wanting. Notably in the *Tæniada* or Tape-worms, and in other parasitic forms, is this the case; such organisms living by the simple imbibition of the already elaborated fluids of their hosts. Yet we cannot doubt that, even in this latter case, the food must, in the interior of the organism, undergo a further degree of elaboration.

Lastly, and in concluding the consideration of this important series of distinctions, it is of importance that the broad relations between the animal and plant series be clearly borne in mind. The illustration formerly adduced—namely, that of expressing the relations of the

two series by drawing two circles so as to touch each other at a point in their circumferences, will, if its terms be correctly appreciated and understood, recall to mind the position of the one kingdom as regards the other.

Each possesses an entity distinct in kind from the other. The two form a great tree, consisting of two main stems, united in their lower part, but diverging from each other the more widely as we proceed upwards. Hence the two economies do not, and cannot, from the nature of the case, form one long linear series, which would have its origin in the lowest plant, and its termination in the highest animal form. The point in the diagram of the circles, in which each circle merges into the other, or the union of the two great stems of the tree, is represented in the real case by the union of the *Protozoa* and *Protophyta*, in the strange and confusing identity of form and relations we have already discussed.

We cannot, by any gradation of any kind, pass from the higher plants to the lower animals, and onwards to the highest animal forms. No such unbroken line or continuous series can be formed, since it is only in their lower boundaries that the animal and plant worlds show any tendency to merge into each other. In other words, the two series are to be placed side by side, as in the circles, and not in any continuous linear arrangement. The higher forms of each kingdom diverge so widely from each other, that it requires no scientific aid or acumen to readily distinguish the nature and relations of either or both.

CHAPTER IV.

Differences between different Organisms—Divisions of Biological Science—Morphology, Physiology, and Distribution—The Differences in "Function"—"Specialisation of Function"—Illustrations and Deductions.

OUR work, so far as it has proceeded, partakes in character of the analytical, inasmuch as we have been endeavouring to separate out and to distinguish the great groups of natural objects; and to clearly set before us the special characteristics of each division. We have thus defined, so far as is possible, the two great series of organic or living beings. The next step in our process of analysis and separation consists in the endeavour to discover the most philosophic and trustworthy mode by which any individual organism, or group of organisms, can be separated or distinguished from another organism or group.

And the progress of biological science has in no case left clearer proofs of its advance, than in the improved and thoroughly scientific basis on which the principles of mapping out the differences between different organisms have been founded. The older systems of noting these differences were crude and unsatisfactory, and were founded on supposed distinctions, drawn from mere external configuration, and without any regard to internal structure or organisation. As a consequence, the ultimate scheme of separation or classification of the organic series was, as we shall hereafter see, a thoroughly artificial one; based on self-constituted principles, and entirely ignoring the details of structure and function, on which alone it is possible to construct a true and reliable system of classification.

Two great principles aid us in obtaining a sure idea of the differences between the members of either animal or

plant series. The first of these is termed *Morphology*, and relates to those distinctions which we may draw between two organisms, by simply investigating their *structure*. The second principle is known as that of *Physiology*; and this latter bases its grounds of distinction on the differences which it elucidates from a consideration of the mode in which the *functions* of life are carried on in each organism respectively. Given two organisms, then, concerning which we wish to decide as to the proper place of each in the scale of being, we can thus consider each from two distinct yet connected points of view. We may compare the *structure* of the one with the structure of the other, and determine their relations by a study of their *Morphology*; or we may observe how the processes or *functions* of life are carried on in each, and by aid of *Physiology* arrive at a conclusion as to which is to be regarded the more highly organised of the two.

Before proceeding to note the chief ideas involved in each process, it may be well to observe the subordinate divisions, which are included under the several departments of Morphology, Physiology, and Distribution. The tabular view appended will serve to show at a glance the classification of these sciences :—

BIOLOGY—"SCIENCE OF LIVING BEINGS."

Differences between different organisms or groups of organisms investigated under the sciences of—

I.—MORPHOLOGY (Science of Form)	1. Anatomy. 2. Embryology or Development. 3. Taxonomy or Classification.	
II.—PHYSIOLOGY (Science of Function)	1. Function of Nutrition or Alimentation.	Digestion, Absorption, Circulation, Respiration.
	2. Function of Reproduction.	
	3. Function of Correlation, Innervation, or Irritability.	
III.—DISTRIBUTION	1. In Space (Geographical). 2. In Time (Geological).	

The science of *Morphology*, then, includes three subdivisions, each of which deals with a subordinate part of the *structural* relations of the organism. (1) *Anatomy* thus investigates for us the structure of the adult being—of the organism in its fully-grown state. Our knowledge of its structure, however, cannot be said to be completed with a review of its adult state; and accordingly we trace its early life-history, by aid of the second branch of the science, that of (2) *Embryology* or *Development*. We now know the organism thoroughly as to its structure; as the perfect animal, and in its various stages of development also. The third division of Morphology is that of (3) *Taxonomy* or *Classification*, and this principle is brought into use, when, knowing the structure of several organisms, we compare them together, with a view to determine their relative place in our scheme of arrangement. This latter head might in this respect be termed "*Comparative Morphology*." To these three divisions of Morphology some authorities add a fourth—namely, *Histology*; by which branch we investigate the minute structure of the tissues or intimate parts of the organism. This latter science might therefore be appropriately named "*Microscopic Morphology*," since in its pursuit we employ the microscope and allied modes of investigation.

The science of *Physiology* similarly divides itself into three subdivisions, by means of which we gain a complete knowledge of the processes or *functions* of life in the animal or plant. Firstly, we observe how the organism nourishes itself—(1), Function of *Nutrition*—and under this branch of physiological knowledge we investigate the processes of digestion, absorption, circulation, and respiration; or, in other words, those functions which administer to the growth of the being, by providing for the due elaboration of the food. The function of (2) *Reproduction* provides for the propagation of the species; or for the production of new individuals, by which the specific peculiarities of the organism are carried on, and perpetuated in time. Then, lastly, we have the function of (3) *Correlation*, or as it is sometimes termed,

of *Innervation* or *Irritability*. This latter subdivision investigates the relations which an organism maintains with the world in which it lives, which relations are manifested through the nervous system, or through analogous media.

The terms "functions of animal life," and "functions of organic or vegetative life," so frequently occur in connection with the present subject, that it may be well to explain what is meant by these terms. The functions of "organic or vegetative life" are those of *Nutrition* and *Reproduction*; and these latter functions are so called because they are common to all living beings, whether animals or plants. The functions of *Correlation*, on the other hand, are generally regarded as distinctively and essentially peculiar to the *animal* series, and hence these latter functions are spoken of as those of "animal life."

The *Distributional* aspect of biological science divides itself into a twofold arrangement. We ascertain by its (1) *Geographical Distribution* how an organism is distributed in the world as it now exists. We observe under this head the particular tracts or regions it inhabits, or conversely, in what districts it may be or is unknown. And lastly, through (2) *Geological Distribution*, or by means of its *Distribution in Time*, we ascertain if the organism existed in past periods of our earth's history; and if so, whether or not the conditions of the past differed from those under which it may exist in the present day.

To know an animal or a plant fully and completely, we must know it according to the mode and principles of investigation I have just pointed out. In no sense can our knowledge of an organism be said to be complete and final, unless we are fully aware of its Morphology, its Physiology, and its Distribution. Its early life; its period of full development; its functions as a living being: its habitat now and in time past—these are the points which a complete life-history should contain, and which it is the province of a reliable system of examination to furnish.

Resuming the consideration of those distinctions which

separate different organisms from one another, we now note how morphology and physiology, respectively investigating for us the details of structure and function, enable us to form a correct idea of the relations which exist between the members or groups of either life-series. We observe without difficulty very many differences between animals on the one hand, or between plants on the other. Differences these, which we may include under the heads of form, colour, size, etc., and which may readily enough serve the purposes of a popular classification or arrangement. But, scientifically regarded, we must endeavour to ascertain such differences after a reliable mode; and thus we call to aid the generalisations which a correct system of Morphology and Physiology alone can give.

The differences between different living beings are therefore capable of being investigated under either or both of these divisions: in other words, the differences either relate to the *form* and *structure* of the organism, or to the manner in which the *functions* of its body are carried on. Or, lastly, we may employ both of these means, conjointly, to aid us in our work.

The *morphological* or structural differences are investigated under the head of "Morphological Type;" and the *physiological* or functional differences collectively constitute what is known as "Specialisation of Functions." We shall most profitably and readily arrive at a clear understanding of both, if we commence with the consideration of the differences in "function."

By "specialisation of functions" we conveniently and shortly mean to express the fact that an organism is physiologically simple when the functions of its body are simple, and are subserved by organs or tissues of correspondingly elementary character. Hence the organism physiologically increases in complexity and in perfection of organisation, according as its *functions* are more complex; or, to use the more expressive term, as its functions become more and more "specialised." At the one extremity of either organic series we have organ-

isms physiologically simple, and with functions "unspecialised:" at the other extremity "specialisation of functions" attains its maximum in the most highly organised forms. Let us briefly trace the progress of the specialisation of the nutritive function, as materially assisting us to understand the meaning and application of the term.

The first stage finds a convenient illustration in such a *Protozoic* form as the *Amœba* (Fig. 1, *a b*), or better still in its nearly allied neighbours the *Foraminifera* (Fig. 2, *a b*). In either case, the phenomena of life are primitive and simple to the last degree, and in the *Amœba* these phenomena may be very conveniently studied. Its body is composed of a minute shapeless mass of sarcode or protoplasm, destitute of any defined outline, and exhibiting but the faintest traces of organisation. We look in vain for any defined or even rudimentary stomach-sac, or digestive apparatus of any kind. When the function of nutrition is brought into play, we see it thrusting out its protoplasmic body into finger-like processes (Fig. 1, *a*), by means of which it seizes any particles of nutrient matter. These nutrient particles are drawn into the interior of the body, and the extemporised arms or fingers soon disappear. Around each particle of food thus thrust into the substance of the body, a little clear space forms, and gradually the minute morsel is digested in this temporary and extemporised "stomach." We cannot be certain of the existence in the *Amœba* of any definite organs for the circulation of the nutrient fluid which we may suppose to be thus elaborated from the food; although the function of hearts has been ascribed to certain little clear spaces, termed "contractile vesicles," and which are seen to contract and expand in a regular and defined manner. The innutritious or indigestible portions of the food, or the waste matters of the system, are simply cast out of the body from any portion of its surface; that is, no defined channel for the conveyance of such material from the system is found in the present instance. No distinct respiratory

or breathing organs exist in the *Amœba*, which thus presents us with a form, lingering as it were, on the very verge of existence.

Now let us clearly understand the state of matters observable in the *Amœba*. Firstly, then, we find that no part of the body is "specialised," or set aside to perform the special functions of a stomach; and no specialised organs for seizing the food are present. Any part of the body serves the animal as a stomach, just as any portion of the body-wall can be thrust out to grasp or entangle the particles of food. And as the digestive function is not specialised, so neither are the respiratory, nor, in all probability, the circulatory systems. Specialisation of functions, in short, has not commenced in the *Amœba*. The simple functions of its body are subserved by means apparently and infinitely more simple than the functions themselves.

A step higher in the scale brings us to a form in which we find a certain degree of specialisation of the nutritive function. The common Fresh-Water Polype, or *Hydra*

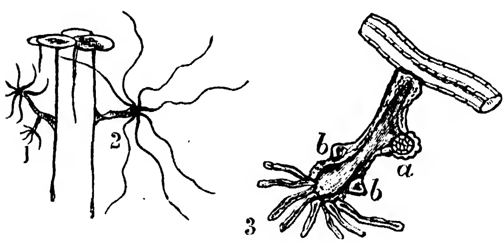


Fig. 7. HYDROZOA.

1. *Hydra viridis*, attached to root of duckweed, with young *Hydra* budding from the side of the parent. 2. *Hydra fusca*, the "long-armed" *Hydra*. 3. *Hydra viridis* (greatly magnified), showing tentacles, ovarium (*a*), and spermatozoic receptacles (*b b*).

(Fig. 7, 1 2 3), found attached to the roots of duckweed and other aquatic plants in most of our ponds, exemplifies the second stage in our investigation. This organism consists of a minute tubelike body, attached by a

root-like extremity to any fixed object, and possessing at its free or unattached end a mouth surrounded by a circle of tentacles. A diagrammatic section of the *Hydra's* body (Fig. 8) reveals a very simple and primitive organisation. We find this body to be composed of a simple tube, with double walls (*a b*), terminating superiorly in a mouth (*d*), and tentacles (*c*). The tentacles serve to grasp the food and convey it to the mouth, whilst the general and simple cavity of the body (*e*) serves the purpose of a stomach. We therefore observe in the present case an advance on the *Amœba's* primitive structure. We find the function of prehension, or that of seizing the food, subserved by special organs, the "tentacles"—in other words, the function of prehension is "specialised;" and we also observe that a distinct mouth exists and is specialised, but here the process of differentiation ends in the *Hydra*. No distinct stomach as yet is found, and we have seen that the general cavity of the body (*e*), does duty as a digestive sac. Neither does any special channel exist for the elimination from the body of the innutritious products of digestion; the refuse material of the body being rejected by the oral aperture (*d*).

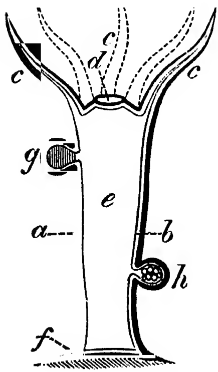


Fig. 8. Section of Hydra. (*Cœlenterata*).

a, Ectoderm; *b*, endoderm; *c c c*, tentacles; *d*, mouth; *e*, "somatic" cavity, or general cavity of the body; *f*, attached portion or "hydrorhiza;" *g*, spermarium or testis; *h*, ovarium or ovary.

A further stage awaits our examination in the *Flustra* or Sea-mat (Fig. 6, *a b*), the structure of which has already been described. If we magnify and diagrammatise a single cell of the *Flustra*, as in Fig. 9, we shall find a very important and marked advance on the *Hydra*. We find a mouth (*b*), and tentacles (*a*) as before, but we also

observe that in addition a distinct stomach (*d*) is specialised or differentiated from the general cavity of the body; and we further notice that from the stomach an intestine (*e*) is continued, terminating by a distinct anal aperture (*f*), and serving for the conveyance from the system of the effete or useless digestive products. Specialisation has advanced in the present case in a marked degree, although as yet we find no distinct circulatory or respiratory organs. In the *Flustra*, the nutritive fluid elaborated from the food simply passes from the digestive system into the cavity of the body (*h*), and is kept circulating throughout the body-cavity by means of the constant action of the little hair-like bodies or "cilia" which line the inner wall of the cell. The function of respiration is in all probability subserved by the ciliated tentacles (*a*) of each little "polypide."

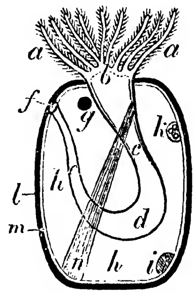


FIG. 9. FLUSTRA.

Diagrammatic section of a single cell of *Flustra* or "Sea-mat" (greatly magnified): *a a*, ciliated tentacles; *b*, mouth; c. gullet; *d*, stomach; *e*, intestine; *f*, anus; *g*, nervous ganglion; *h h*, general cavity of body; *i*, testis; *k*, ovary; *l*, ectocyst, or outer membrane of body; *m*, endocyst, or inner membrane of body; *n*, retractor muscle, by the action of which the animal ,can withdraw the ciliated tentacles.

In the *Snail* or *Whelk* (Fig. 10), we reach a further stage in the process of differentiation of the nutritive function. A complicated organisation is here presented to our notice, and we find that, in addition to the simple stomach and intestine of the *Flustra*, many organs and structures, each fulfilling a definite part and share in the digestive process, are now added. Salivary glands (*e*); a large liver (*i*), furnishing bile, one of the most important of the digestive fluids; a distinct heart (*s t*) and blood-vessels circulating the elaborated products of digestion; and highly developed gills (*p*) or breathing organs for purifying the blood—all testify to the extent and degree

of complication to which the function has, in the present instance, attained.

Then, lastly, if we advance to the consideration of a

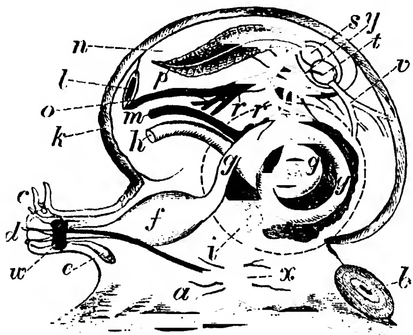


Fig. 10. Diagrammatic Section of Snail.

a, foot; *b*, operculum; *c*, tentacles; *d*, mouth; *e*, salivary gland; *f*, stomach; *g g*, intestine; *h*, anus; *i*, liver; *l*, aperture of gill-chamber; *m*, oviduct; *n*, gill-chamber; *o*, floor of gill-chamber; *p*, gill or breathing-organ; *s t*, heart; *w*, "cephalic," *x*, "pedal," and *y*, "branchial" ganglia.

form high in the scale, such as a *Mammal* (Fig. 11), we shall find the process of specialisation still further improved upon and advanced.

Let us now take a retrospective view of these various stages, and endeavour to gain a true idea of the significance of the process of differentiation. In the *Amœba* any part of the body subserved the nutritive function, and its specialisation in that animalcule could hardly be said to have commenced. In the *Hydra* we found the presence of a distinct mouth, tentacles, and body-cavity, to evince a primary, but still decided, stage of advance on the simplicity of the *Amœba's* organisation. In the *Flustra* the process was observed to be truly specialised; distinct organs and parts being devoted to the performance of the nutritive function. And lastly, in the complicated organisation of the *Whelk*, or *Mammal*, the process reached, respectively, a great and the

highest degree of differentiation to which it could attain. What, then, is the essential difference which physiology will teach us between the simple *Amœba* and the complicated Mollusc or Mammal? The *Amœba* and Whelk nourish themselves equally well. The process of nutrition is as perfect in the *Amœba*, so far as its result goes, as it is in the Whelk. But the *mode* in

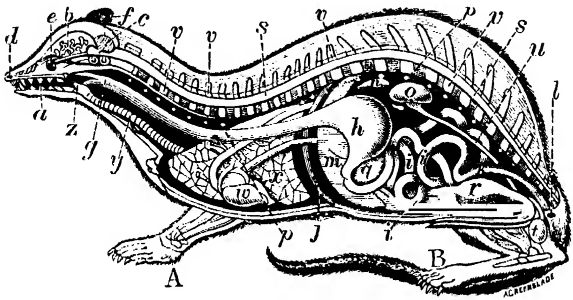


Fig. 11. Ideal Section of Mammal. (Owen.)

A, fore-limb; B, hind-limb; *a*, mouth; *b c*, brain; *d*, nostril; *e*, eye; *f*, ear; *g*, gullet; *h*, stomach; *i i*, intestine; *j*, midriff; *k*, terminal portion of intestine; *l*, anus; *m*, liver; *n*, spleen; *o*, kidney; *p p*, sympathetic nervous system; *r*, urinary bladder; *s s*, spinal cord; *v v v*, vertebral column; *w*, heart; *x*, lung; *y*, windpipe; *z*, epiglottis.

which the result is attained varies greatly in the two cases, and it is exactly this variation which physiology expresses as the *functional* distinction between different organisms.

The simple function in the *Amœba*, subserved by its equally simple protoplasmic body, is broken up in the Whelk, for example, into a complicated series of secondary functions; these secondary functions being subserved by organs which are specialised or set aside, each for the performance of a special duty. Thus it is clear that with the growth in complexity of a function we must also have a corresponding increase in the complexity of our apparatus. It would be obviously useless to suppose or expect that the simple protoplasm of the *Amœba*

should perform the complex functions subserved by the special organs and systems of the Whelk; and therefore it is that we find specialisation of functions and specialisation of organs going "hand-in-hand." Nature, in this view, never employs a physiological "maid-of-all-work" or "Jack-of-all-trades." Where the duties are many and varied, the apparatus is also varied; and hence the term "physiological division of labour," applied to the "specialisation of functions" by Milne Edwards, very happily expresses a just generalisation of the process. The Amœba's body, indeed, is comparable to a factory where raw material is perfectly prepared after a very simple fashion, involving no division of labour, and to serve an equally simple purpose. The body of the Whelk or Mammal is similarly comparable to a factory, in which the raw material is prepared after a different fashion, in a complicated manner, and involving an immense division of labour in every department of the process. The same result is attained relatively to each organism, namely, that of perfectly nourishing itself; but the means used to that end are widely different in the two cases. It is this difference which the principle of the "specialisation of function" expresses; and, physiologically speaking, therefore, an animal is high or low, according as its functions are specialised to a greater or less degree.

To use Huxley's words—"In the lowest organism all parts are competent to perform all functions, and one and the same portion of protoplasm may successively take on the function of feeding, moving, or reproducing apparatus. In the highest, on the contrary, a great number of parts combine to perform each function, each part doing its allotted share of the work with great accuracy and efficiency, but being useless for any other purpose."

What has just been illustrated by aid of the function of nutrition might equally well have been exemplified by that of "reproduction," and, though perhaps not with so strict a result, by the function of "innervation" also. We know so little concerning the conditions determining the function of relation in the lowest organisms,

that we could not, with ease or certainty, employ this particular function to illustrate the process of specialisation through its various stages. At the same time, we are not at all inclined to believe with those who assert that the comparison between the function of relation in the highest and in the lowest animal organisms is one hardly fair or admissible. We do not doubt that such forms as the *Amœba* and *Foraminifera* possess a general sensibility in lieu of the more localised sensations indicative of and dependent upon the presence of a distinct nervous system. This idea is strengthened, as will hereafter be shown, by the results of recent investigations into the nature of "bioplasm;" and we appear to be on the verge of the demonstration of the elements of a sensory apparatus even in the lowest organisms.

There is certainly nothing unreasonable in the idea that the lower animal organisms possess means for carrying on the function of innervation; these means being present and exercised, in an imperfect degree no doubt when compared with the definite nervous apparatus of higher forms, but partaking, in common with the other systems and functions, of that general want of specialisation which we have seen to characterise the *Protozoa* generally.

CHAPTER V.

Morphological Differences between different Organisms—"Morphological Types:" their Nature and Constitution—Definition and Consideration of the Six Types or Sub-kingdoms: Protozoa, Cœlenterata, Echinozoa or Annuloida, Annulosa, Mollusca, Vertebrata.

THE differences between different organisms which the study of *Morphology* brings to light are collectively stated under the term "Morphological Types." A careful study of the structural relations of animal forms has revealed the fact that the entire animal series may be divided into six great types or plans of structure; in other words, every animal, considered in relation to its form or morphology, is referable to one or other of these six primary types. Accordingly, when we say that two animals belong to the same "morphological type," we mean that their bodies, however diverse and unlike in external appearance, are constructed or built up on the same primary structural type or plan. And the influence of this important generalisation on the progress of natural science cannot be too highly estimated.

Agreeing in fundamental structure, however, it does not necessarily follow that any two forms should also correspond in the degree to which the "specialisation of functions" is carried out in the economy of each. Hence, having ascertained that two forms agree in being built up on the same fundamental plan, we may employ the physiological means of the "specialisation of functions" to separate and distinguish differences between them. We may thus ascertain that a crab, an insect, and a worm, belong to the same "morphological type;" but a very slight examination of these forms will suffice to show us that the degree to which the "specialisation of functions"

is carried, differs materially in the three cases. We should, therefore, in conformity with our two principles, place them *morphologically* in the same "morphological type;" whilst *physiologically* we should assign each a higher or lower place in the type, according as its functions were specialised to a greater or less degree. These considerations, if borne in mind, will greatly assist us in forming a correct idea of the principles of classification.

Whilst every animal is thus the "resultant" of a morphological tendency on the one hand, and of a physiological tendency on the other, it is exceedingly difficult to give any accurate or absolute definition of what is to be regarded as a true or exact "morphological type;" nor are zoologists entirely agreed as to the correct constitution of certain "types" generally recognised as such. All that need be said, however, on this point, is embraced in the idea that similarity of fundamental structure, as revealed by morphology and development, is sufficient and requisite to constitute a "morphological type."

According to the most generally received and accepted ideas, six primary types or plans of structure are to be defined in the animal series. These types, under the name of "sub-kingdoms," are employed as a basis for our modern classification of the animal and plant worlds, as will be hereafter shown. In the present instance, an enumeration of the chief characteristics of each type will serve to familiarise the student with the great divisions into which the animal series is divided, and will also aid him in the consideration of systematic questions and arrangements.

The animal world is therefore divided into six morphological types or "sub-kingdoms." These, commencing with the lowest in point of structure, are respectively known as the (1) *Protozoa*, (2) *Cœlenterata*, (3) *Echinozoa* or *Annuloida*, (4) *Annulosa*, (5) *Mollusca*, (6) *Vertebrata*. The accompanying illustrations and diagrams will serve to fix the chief structural points of distinction on the mind of the student; and it may be remarked that a correct idea of the "plan" of each type, as diagram-

matised in the figures, will be found of great value in assisting the mind to recognise and retain the essential characters of the respective types.

I. PROTOZOA (Fig. 12, A).—As implied by the name *Protozoa* (*protos*, first; *zoön*, animal), the forms included in this sub-kingdom constitute the most lowly-organised series of the animal world. For the most part the *Protozoa* are aquatic and of microscopic size, and they may exist either as simple and single animals, or in a compound state.

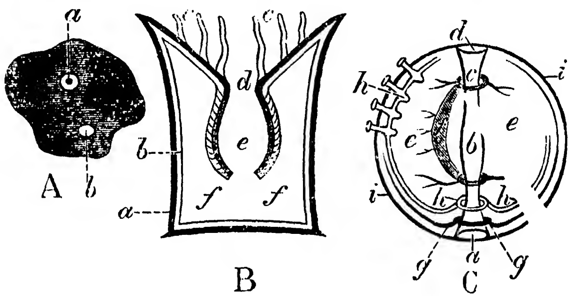


Fig. 12. MORPHOLOGICAL TYPES.

A, Diagrammatic plan of *Protozoön*: *a*, nucleus; *b*, contractile vesicle. B, Plan of *Cœlenterate*: *a*, ectoderm; *b*, endoderm; *c*, tentacles; *d*, mouth; *e*, stomach; *f f*, body-cavity. C, Plan of *Echinozoön*: *a*, mouth; *b*, stomach; *c*, intestine; *d*, anus; *e*, body-cavity; *f*, heart and blood system; *g*, nervous system; *h*, water-vascular or ambulacral system; *i i*, wall of body.

Their bodies are composed of the structureless albuminous material known as "bioplasm," "sarcode," or "protoplasm," and they exhibit throughout a total absence of "symmetry," that is, a definite arrangement of the parts or elements of form. The *Protozoa* are generally destitute of distinct organs of nutrition, circulation, respiration, and innervation. Their reproduction is sexual, or may be effected after asexual methods, as by "gemmation" or "budding," and by simple "fission" or division of the body-substance. In most, if not in all, a solid and more or less central particle, concerned in reproduction, and

termed the "nucleus" (Fig. 12, A, *a*), is found. The "nucleus" may contain a smaller particle known as the "nucleolus." The ultimate constitution of the bodies of the *Protozoa*, as revealed by histology, is generally "unicellular;" that is, consisting of a single and simple "cell." The diagrammatic "plan" of the Protozoa (Fig. 12, A), might therefore be characterised as being no plan at all; since the group is distinguished, as we have just seen, rather by its want of definite and positive characters than by the possession of such distinctive features. An irregular ink-blot, in this respect, might, with the addition of a nucleus, correctly enough express the architectural plan on which the bodies of the Protozoa are built up.

Table of the Divisions of PROTOZOA.

CLASS I.—*Gregarinida*. *Ex*. Gregarina.
,, II.—*Rhizopoda*. *Ex*. Amœba (Fig. 1), Foraminifera (Fig. 2), Radiolaria (Fig. 2).
,, III.—*Spongida*. *Ex*. Sponges.
,, IV.—*Infusoria*. *Ex*. Paramœcium, Vorticella, etc. (Figs. 5 and 22).

II. CŒLENTERATA (Fig. 12, B).—The forms included in this sub-kingdom, or type, are primarily distinguished by the fact, that in all, the general cavity of the body, or "somatic" cavity (*f*), freely communicates with the digestive or alimentary system (*e*), when present; the somatic, or body-cavity of the *Cœlenterata*, being thus in free communication with the outer world through the mouth (*d*). This is simply another mode of expressing the fact that the digestive system (*e*) is but incompletely specialised from the cavity of the body (*f*). Indeed, the term *Cœlenterata* itself, is meant to express this primary characteristic of the sub-kingdom. In this type of structure a distinct "hæmal" blood-vascular, or circulatory system, is wanting; and, save in a few doubtful cases, a "neural" or nervous system is also absent. In the tissues of most, if not of all *Cœlenterata*, certain bodies of variable, but generally of minute size, and termed "thread-cells," or "cnidæ," are found. The function of these urticating or stinging cells is that of offensive or defensive organs, and by means of these bodies the *Cœlenterata*

are enabled to paralyse or kill their prey. Histologically examined, the tissues of the *Cœlenterata* are divisible into two primary layers; the outer layer being termed the "ectoderm" (*a*), and the inner layer the "endoderm" (*b*); and this latter membrane of itself may subserve the digestive function, or may become specialised to form a distinct stomach. True cell-structures, aggregated together, and forming membranes, are thus present in the *Cœlenterata;* this condition forming a striking contrast to the general unicellular structure of the *Protozoa.* Reproduction in the *Cœlenterata* may take place sexually or asexually; the process of "gemmation," or "budding," being seen very typically in the present instance. Lastly, the "symmetry," or disposition of parts in the *Cœlenterata,* is of the "radial" description, but their bodies are also "bilaterally" arranged. The meaning and import of these symmetrical relations will be fully discussed in a future chapter.

Table of the Divisions of CŒLENTERATA.

CLASS I.—*Hydrozoa.*	Cœlenterata, in which the digestive or alimentary sac is not separated from the general cavity of the body; external reproductive organs. *Ex.* Hydra (Figs. 7 and 8), Medusæ, Sea-firs, etc. etc.
CLASS II.—*Actinozoa.*	Cœlenterata, in which a specialised and distinct digestive sac is contained within, and freely communicates with the body-cavity (Fig. 12, B); reproductive organs internal. *Ex.* Sea Anemones, Coral Polypes, etc. etc.

III. ECHINOZOA OR ANNULOIDA (Fig. 12, C).—This third sub-kingdom possesses a double name, or rather is known under these two designations. Naturalists are by no means agreed whether or not the *Echinozoa* should be regarded as constituting a distinct morphological type or sub-kingdom; and certainly, when we consider the apparently heterogenous nature of the included forms, the objection to its constitution becomes feasible and warranted. Yet it is one thing to admit a defect, but quite another

matter to remedy or improve it; and although repeated attempts have been made to abolish the type, we have not, up to the present time, been presented with an arrangement sufficiently clear or satisfactory to warrant us in disbanding the *Annuloida*, and gathering up anew the scattered members of the group. Although, then, the *Echinozoa* may be considered by some authorities as a kind of "refuge for the destitute," in that it shelters certain forms which, apparently, would not be at home elsewhere, there are not wanting those, on the other hand, who recognise the stable nature of the type, and who claim the recognition of the sub-kingdom, on the ground that it possesses certain very definite characters of its own.

These characteristics are, firstly, the complete specialisation of the alimentary tract (*b c*) from the general or "somatic" cavity of the body (*e*); the digestive system being now complete, and shut off from communication with the body-cavity. In some *Echinozoal* forms a distinct digestive system may be wanting, but in none do we find the communication between the digestive system and body-cavity so characteristic of the *Cœlenterata*. A nervous or neural system (*g*) is developed in all, and a hæmal or blood-vascular system (*f*) is very generally present. But the character of most importance in the *Annuloida*, and which seems to link together the dissimilar forms included in the sub-kingdom, is the very general possession of a peculiar system of canals (*h*) ramifying through the body, communicating with the outer world, and serving for the transmission of water; from which latter fact the very applicable name of "water-vascular" system has been given to this arrangement. This system may be made subservient to locomotion, or may apparently be excretory in function. But its almost invariable presence, notwithstanding diversity in function, argues strongly for its recognition as a character of the group. Reproduction in the *Echinozoa* is generally of the sexual variety, although there are instances in which the process may more or less partake of the nature of an asexual act.

The disposition of the symmetrical elements in the young and in the adult stages of the more typical *Echinozoa* show a wide dissimilarity; and, indeed, partly from this feature in their development, the idea of ranking these forms as a subdivision of the *Annulose* type has, I believe, chiefly sprung. The term *Annuloida*, it may also be mentioned, has been applied to this type of structure, from the same idea of similarity to the next and higher sub-kingdom, that of the *Annulosa*, from which, however, the *Echinozoa* are to be carefully distinguished.

The class *Echinodermata*, represented by the Star-fishes and Sea-urchins, constitute the most typical group of the

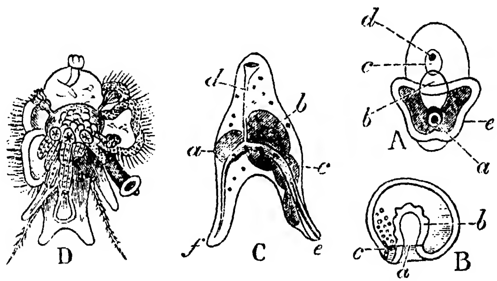


Fig. 13. Development of Echinoderm (after Müller.

A, Earliest stage of embryonic or larval form, showing *a*, mouth; *b*, stomach; *c*, intestine; *d*, anus; *e*, ciliated spheres. B, Later stage of A: *a*, mouth; *b*, intestine; *c*, ciliated bands. C, Further stage, showing larval form known as "Pluteus;" *a*, mouth; *b*, stomach; *c*, intestine; *d*, calcareous skeleton. D, Form of true embryo or "Imago" evolved from the "provisional larva."

sub-kingdom, and it is therefore in these forms that the analogies of the type are to be traced. The development of the young *Echinoderm*, therefore, presents us with a very characteristic phase in the special definition of this particular division of the sub-kingdom. The egg of the *Echinoderm* is first observed as a free and active embryo (Fig. 13), usually ovoid in shape, and propelling itself through the water by aid of the cilia, or hair-like filaments, with which its body is provided. In this state it

appears to resemble much the condition of an Infusorian animalcule, but soon the more important phases of development set in, and the cilia next present a more definite arrangement, and appear to form several transverse bands (Fig. 13, A, *e*) disposed on a body which is now bilaterally symmetrical, that is, equally disposed or arranged on each side of the mesial or middle plane. At this stage of development the body may be provided with lateral processes or appendages; and, generally, we find a calcareous or limy skeleton (Fig. 13, C, *d*) developed within the embryo form, which serves to strengthen and support the rudimentary body. And with the further development of a distinct digestive system in the larval form, the first stage in its progress towards maturity may be said to close.

The next and concluding phases of development consist in the curious production of the adult form from within the body of this embryo, or "provisional larva" (*Bipinnaria*, or *Pluteus*), as it has been called. The upper surface of the embryo now becomes involuted, or driven in upon itself, so as to assume a tubular form; and growing inwards and into the interior of the larva, this tube finally terminates to form a circular vessel, which encircles the œsophagus or gullet of the larva. Soon this rudimentary and rapidly-formed tube and its addenda become converted into the main trunks of the "ambulacral" or "water-vascular" system, and from the germinal matter or "blastema" developed around this tubular formation, the walls of the body, the characteristic skeleton of the adult, and the other systems of the fully-grown Echinoderm, are in due course formed (Fig. 13, D). The larval form itself, at the expense and from the material of which this new body has been constructed, is cast off from the new being, or its remaining parts may be employed in the further elaboration of the perfected form. The symmetry or shape of body in the adult is distinctly and characteristically "radial;" that is, the elements of its form are arranged around a common central point or axis. But, as we have noticed, the symmetry in the young and larval form is bilateral, and it

is this remarkable change of form and its analogies which have induced some observers to classify the *Echinozoa* with the *Annulosa*.

Whilst, therefore, recognising the distinctness of type in the *Echinozoa*, we will form a fuller and truer estimate of their relations if we keep in remembrance the points already stated with reference to their affinities with the higher sub-kingdom.

Table of Divisions of ECHINOZOA.

CLASS I.—*Echinodermata.*—Development of an external "test" or "shell," formed generally of calcareous matter, but sometimes of coriaceous or leathery texture; water-vascular system communicating with exterior, and generally subserving locomotion; symmetry of larva or embryo bilateral (Fig. 15), that of adult "radial." *Ex.* Echini or Sea-urchins; Star-fishes; Crinoids or Sea Lilies; Sea Cucumbers, etc.

CLASS II.—*Scolecida.*—No calcareous integument; water-vascular system not subserving locomotion, but in all probability excretory; hæmal system imperfect or wanting; neural system in form of one or two ganglia or "nerve-masses;" symmetry flattened, bilateral, or rounded, in some cases approaching the segmented type. *Ex.* Tapeworms; Flukes; Wheel Animalcules (Fig. 3), etc.

IV. ANNULOSA (*Articulata*) (Fig. 14).—In the consideration of this type of structure we are to a great extent free from the puzzling questions of affinity which beset the *Echinozoa*. The body in *Annulosa* is typically and characteristically composed of a series of joints, segments, or "somites" (Fig. 14, 1), disposed along a longitudinal axis—that is, arranged one after the other. Each somite or segment is essentially the type of that which precedes it, and the prototype of that which follows it; the "appendages" of the segments being those parts which evince wide and marked differences in function or analogy. In the *Annulosa*, then, is typically seen the arrangement known as the "vegetative or correlative repetition of parts;" an expression conveniently indicating that marked resemblance of parts in the animal economy to each other,

ments, .

which is typically exemplified in the obvious repetition of form and symmetry in the parts of plants. It is needful, however, to distinguish in practice between the nature of mere "parts," so repeated, and distinct "individuals." Thus the segments of a worm repeat each other, and exemplify the expression just noticed; but this is entirely different from the repetition of "forms" in the case of any compound organism, such as a Sea-mat (Fig. 6, *b*) or Tapeworm, in which the elements repeated are true "individuals," and not mere "parts" of a single "individual."

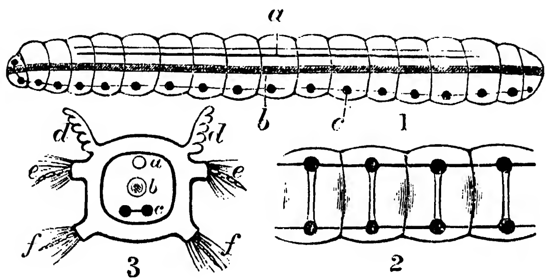


Fig. 14. MORPHOLOGICAL TYPES.

1. Diagrammatic longitudinal section of *Annulose* animal: *a*, blood or hæmal system; *b*, digestive system; *c*, neural or nervous system. 2. Nervous system of *Annulose* animal, viewed from above, and showing the double ventral nervous chain. 3. Transverse section of *Annulose* animal: *a*, blood system; *b*, digestive system; *c*, nervous system; *d d*, gills or breathing organs; *e e* and *f f*, "oars" or locomotive organs.

The symmetry in the present instance is of the kind we term "zonal," a name applied in allusion to the evident "zones" or segments of which the body is composed. But united with the "zonal" symmetry we have also "bilateral" symmetry, since we can divide the body into an equal right and left half.

The "plan" of the structural arrangement is also very distinct. The heart (*a*) is situated dorsally—that is, on the back; whilst the nervous system (*c*) is placed on the ventral surface of the body, or nearest the ground, when

the animal moves; and between these two systems, and thus occupying an intermediate position, we find the alimentary or digestive tract (*b*). In every *Annulose* animal, then, this disposition of parts prevails, but it is certainly to the peculiar form of the nervous axis that we must look for a distinctive character. Viewed laterally, as in a vertical section of the animal (Fig. 14, 1, *c*), made lengthwise through the mesial plane, the nervous axis of the *Annulosa* would appear to consist of a single series of ganglia or nerve-knots; but when we look down upon the floor of the body from above, in an ideal section showing this latter aspect (Fig. 14, 2), we then observe that the nervous cord of the *Annulosa* is typically double, and that two ganglia are disposed in each segment of the body, instead of one, as seen in the former section. This double nervous chain is perforated anteriorly by the alimentary tract, around which, therefore, the nervous cord forms a kind of collar—"œsophageal collar." Such is the typical disposition of the neural axis in the *Annulosa*; and regarding it, the chief points to be borne in mind are its position and conformation; the latter feature, indeed, forming, to Professor Owen's mind, so marked a characteristic of the group, that he has proposed for the *Annulosa* the distinctive term of *Homogangliata*, a name denoting that the nervous system is composed of similar and regularly-disposed ganglia.

The further characters of the sub-kingdom are found in the relative position of the limbs, when these appendages are present. They are regularly disposed in pairs, and are turned towards the nervous side of the body, or that side on which the nervous axis is situated.

Table of the Divisions of Annulosa.

Section A.—*Anarthropoda*—*Annulosa* destitute of jointed limbs articulated to the body.

Class 1. *Gephyrea*—Spoonworms.

,, 2. *Annelida*—Earthworms, Leeches, Sandworms, etc.

Section B.—*Arthropoda*—*Annulosa* possessing jointed limbs articulated to the body.

Class 3. *Myriapoda*—Centipedes, Millepedes.
,, 4. *Insecta*—Insects, Flies, Beetles, Lice, etc.
,, 5. *Arachnida*—Spiders, Mites, Scorpions, etc.
,, 6. *Crustacea*—Lobsters, Crabs, Shrimps, Woodlice, etc.

V. MOLLUSCA (Fig. 15).—The chief characters distinguishing the present type or sub-kingdom are found,

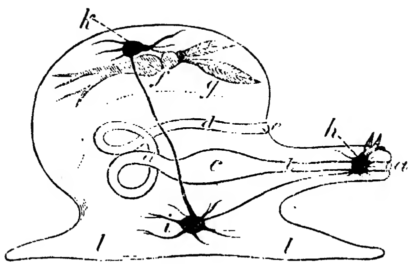


Fig. 15. MORPHOLOGICAL TYPES.

Diagrammatic plan of *Mollusc*: *a*, mouth; *b*, gullet; *c*, stomach; *d d*, intestine; *e*, anus; *f*, heart; *g*, gills; *h*, "cephalic" ganglia; *i*, "pedal" ganglia; *k*, "branchial" or "parieto-splanchnic" ganglia; *l l*, foot.

firstly, in the absence of distinct segmentation and serial appendages; secondly, in the general presence of an external calcareous support or "shell;" and, thirdly, in the characteristically irregular disposition of the nervous system. Besides these principal characteristics, several points of minor importance are to be noticed.

The name Mollusca (Lat. *mollis*, soft) originated with Cuvier, and was applied to the animals included in this group, from the general *softness* of their bodies, a feature of no distinctive value, which is common, in a greater or less degree, to the other divisions of the animal series; and which, moreover, from the general possession by the *Mollusca* of characteristic *hard* parts in their shells, cannot be said to be either strictly or correctly applicable to them as a distinctive point. Still, the name has been retained, and it serves, apart from its derivation, as well as any other, to designate this large and important group of beings.

Firstly, the *Mollusca* do not exhibit any definite

segmentation or division of the body, such as we find in the *Annulosa;* and this first point will at once serve to distinguish any *Mollusc* from any ordinary *Annulose* form.

A "shell" is generally, though not always present, and this exoskeleton generally bears a definite relation to the breathing organs of the animal. The shell varies greatly in form and composition, and, as we have remarked, may be wanting in many instances.

The functions of nutrition and reproduction in *Mollusca* usually exhibit a high degree of specialisation; but it must also be borne in mind that the respiratory and circulatory systems may exist in a very rudimentary condition, or may be wanting altogether. The alimentary tract (*a b c d*) is, however, always well developed, independently of the perfection to which the hæmal or respiratory systems may attain. The digestive tract in *Mollusca* is rarely straight, as in many *Annulosa*, being usually bent upon itself (Fig. 15), so that the anal opening (*e*) is situated in proximity to the mouth (*a*). The symmetry of the Mollusc is typically of the bilateral description; the equal or bilateral halves of the body existing on each side of a median line, which, however, in the present case is slightly curved. When separate organs of locomotion are developed, they are of soft character, usually single, and placed in the middle line of the body (*l l*).

Reproduction in *Mollusca* is generally sexual, but in a few instances the asexual method, known as "gemmation," or "budding," is to be noticed. In most of the *Mollusca* the sexes are united in the same individual, but in many forms they are found distinct.

The disposition of the nervous system forms the last and most important feature to be considered in discussing the distinctive characters of the *Mollusca*. In the "plan" (Fig. 15) the neural axis (*h i k*) of the *Mollusca* is seen to be irregularly disposed over the body, and this scattered condition of the ganglia or nerve-centres has suggested to Professor Owen the term *Heterogangliata;* a name used in opposition to that of *Homogangliata*, which

latter term we have already seen to be applied to the *Annulosa.* In the typical Mollusc the nervous system consists of three chief pairs of ganglia, known respectively as the "supra-œsophageal," or "cephalic" (*h*); the "pedal" (*i*); and the "parieto-splanchnic," or "branchial" (*k*). These three great centres are connected together by nervous cords, and exist, as their respective names imply, in certain defined regions of the body. Thus the "supra-œsophageal" or "cephalic" ganglia (*h*) are situated in the region of the head; the "pedal" ganglia (*i*) in the vicinity of the "foot" or locomotive organ; and the "parieto-splanchnic," or "branchial" ganglia (*k*), in the neighbourhood of the heart (*f*), gills (*g*), and adjacent viscera. This disposition of the nervous axis constitutes, therefore, a marked diagnostic feature of the *Molluscan* type of structure.

Table of the Divisions of MOLLUSCA.

SECTION A. *Molluscoida* or *Lower Mollusca.*—Mollusca in which a single nervous ganglion, or single pair of ganglia, exists. Heart absent or rudimentary.

Class 1. *Polyzoa.*—*Ex.* Flustra, Sea-mats (Fig. 6), etc.
,, 2. *Tunicata.*—*Ex.* Sea-squirts, Salpa, etc.
,, 3. *Brachiopoda.*—*Ex.* Terebratula, Lamp-shells, etc.

SECTION B. *Mollusca Proper* or *Higher Mollusca.*—Mollusca in which three principal pairs of ganglia are present. Heart always well developed, and consisting at least of two chambers.

Class 4. *Lamellibranchiata.*—*Ex.* Oysters, Cockles, Mussels, etc.
,, 5. *Gasteropoda.*—*Ex.* Snails, Whelks, Sea-Lemons, etc.
,, 6. *Pteropoda.*—*Ex.* "Whale's-food," Clio, Hyalaea, etc.
,, 7. *Cephalopoda.*—*Ex.* Cuttle-fishes.

VERTEBRATA (Fig. 16).—The first and most distinctive character of this, the last and highest group of the animal series, is found in the possession by every vertebrate of a column or rod (*a*), generally of osseous or bony material, usually segmented, and known as the "vertebral column," "spine," or "backbone." This column—from the presence of which the sub-kingdom derives its name—we find to be typically provided with a number of upper or "dorsal" arches, and a number of lower or "ven-

tral" arches (Fig. 16), corresponding and related to the segments of which the column is composed. The segmentation of the column follows the same order and arrangement we have already observed in the body of the annulose animal as a whole. It is thus composed of a series of joints or segments arranged one after another in a longi tudinal axis. The chief nervous centres (*b*) of the *Vertebrate* are contained within the bony canal formed by the upper arches of the vertebral column; whilst the ali-

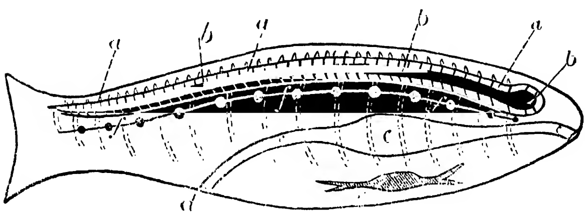


Fig. 16. MORPHOLOGICAL TYPES.

Diagrammatic plan of Vertebrate type; *a a a*, Vertebral column or spine, the upper arches of which enclose the brain and spinal cord; *b b b*, "cerebro-spinal" nervous system or axis, consisting of the brain and spinal cord; *c c*, digestive or alimentary system; *d*, anus; *e*, hæmal or blood-vascular system; *f f f*, "sympathetic" or "ganglionic" nervous system. The dotted lines represent the lower or visceral arches of the vertebral column (represented in chief by the ribs), which enclose the general viscera of the body.

mentary (*c*), blood-vascular (*e*), and other systems, are enclosed by the lower or "ventral" arches. The relative position of the various systems is the reverse of that seen in the *Annulosa* and *Mollusca*; and the ideal "plan" of the vertebrate body (Fig. 16) therefore shows us the nervous axis (*b*) situated dorsally, the heart (*e*) placed ventrally, and the alimentary tract (*c*) occupying as before a central or intermediate position.

A clearer conception of this arrangement is seen in a transverse section of the *Vertebrate* body, and in its comparison (Fig. 17, B) with a similar section of the body of an *Invertebrate* animal (Fig. 17, A). Thus we find

that the *Vertebrate* body consists of two tubes — a "dorsal" (p^2) and a "ventral" tube (p^1)—lying parallel to each other. The upper or dorsal tube, formed by the spinal column and its upper arches, contains the chief nervous centres (n^2), consisting of the brain and spinal cord, and from this feature the upper tube of the *Vertebrate* has been termed the "neural tube." The lower or "ventral" tube, formed by the lower arches of the vertebral column, contains the organs pertaining to the functions of "organic life," and accordingly we find in this latter tube the heart (h) occupying a ventral position, the alimentary canal (a) in the centre, and above this latter, the nerves regulating the functions of organic life (n^1), and collectively constituting what is known as the "sympathetic" nervous system. This lower tube of the *Vertebrate* (p^1), from its containing the viscera

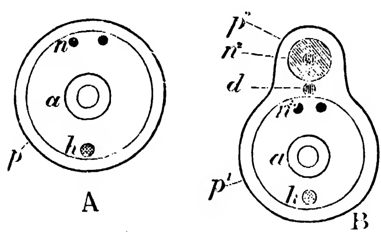


Fig. 17. Comparative Morphology of Vertebrate and Invertebrate.

A, Diagrammatic transverse section of *Invertebrate* animal: a, digestive or alimentary system; h, hæmal or blood-vascular system; n, neural or nervous system; p, walls of body. B, Similar section of *Vertebrate*: a, alimentary system; d, notochord; h, hæmal system; n^1, sympathetic nervous system; n^2, cerebro-spinal nervous system; p^1, walls of body; p^2, walls of neural or nervous canal.

generally of the body, is sometimes spoken of as the "visceral" tube, being so termed in contradistinction to the upper and "neural" tube (p^2).

The transverse section of the body of any *Invertebrate* (Fig. 17, A), on the contrary, shows us that it consists of a single tube only; and that in this single tube, which corresponds generally to the "visceral" tube of the *Verte-*

brate, all the organs of the body are contained. The "neural" tube of the *Vertebrate* (p^2) is therefore entirely unrepresented in the *Invertebrate* body, and this specialisation of the nervous centres is accordingly to be remembered as one of the most distinctive features of *Vertebrate* organisation.

The fact of every *Vertebrate* possessing, as previously stated, a column or rod, generally of bony material, and usually segmented, forms a second character of importance. But it is to be remembered, at the same time, that all vertebrates do not possess such a structure in its entirety and perfection. A few of the lower members of the sub-kingdom do not possess a vertebral column of perfect structure, but in lieu thereof they are provided with a rod-like structure, termed the "notochord," or "chorda dorsalis" (Fig. 17, B, *d*), which represents the vertebral column of higher forms in a rudimentary stage of development. In such lower vertebrate forms, then, the development of the column appears to be retarded or abortive; but, as every vertebrate animal in its early life possesses a "notochord," our first definition might be more correctly rendered by stating that this latter structure is thoroughly characteristic of all *Vertebrata* in the embryonic period of their existence.

The formation of this "notochord" in the production of the *Vertebrate* form is exceedingly interesting, from a developmental point of view. At an early stage in the progress towards maturity, the upper part of the ovum or egg becomes elevated on each side to form two parallel ridges, enclosing a groove known to embryologists as the "primitive groove." Shortly the margins of these ridges unite in the middle line to form a continuous canal, in the centre of the floor of which a rod-like body of cellular structure is developed. This rod-like body is the "notochord" (*d*), which subsequent phases of growth develop in the higher forms into the vertebral column, but which, in a few lower forms of vertebrate life, remains throughout existence in its primitive state.

The symmetry of the *Vertebrate* type corresponds in

character to that of the *Annulose* sub-kingdom. The bilateral condition and zonal arrangement are both present; the latter being typically seen in the segmented disposition of the vertebral column, and to some extent in the body as a whole also.

The vertebrate skeleton is typically *internal*, and this condition contrasts with that of the skeleton in invertebrata, in which it is external to the body. The limbs are never more than four in any *Vertebrate*, and are supported by appendicular elements of the skeleton. They are unlike the limbs of the *Annulosa* in being so disposed that they are turned away from the region of the body in which the chief centres of the nervous system are placed.

The various systems of the body partake of the high degree of specialisation consistent with the advanced character of the morphological type. It is worthy of notice, as a distinctive feature, and one which contrasts with the analogous arrangement in the *Invertebrata*, that the œsophagus or gullet of the *Vertebrata* does not perforate the nervous centres, but deflects from the course of the nervous axis, and opens upon the side of the body opposite to the neural system. The jaws of *Vertebrates*, when present, are always parts of the head, and are never represented, as in *Invertebrates*, by modified limbs, or by hard structures developed in the lining membrane of the alimentary or digestive tract. The heart, in every instance except one, is single, and there exists in all cases a closed system of blood-vessels; this arrangement differing entirely from the imperfect circulation of many *Invertebrate* forms. A certain portion of the impure or venous blood in the *Vertebrata* is collected into a large venous trunk, the "portal" vein, by which it is sent to the liver; and from this supply of blood the bile is elaborated by the latter organ. Such an arrangement is purely characteristic of *Vertebrate* forms.

Reproduction in *Vertebrates* takes place only by sexual methods; and the sexes are invariably situated in different individuals.

Lastly, in the development of the *Vertebrate* ovum, we

can trace many points of peculiar and distinctive interest. We have already seen how the characteristic features of the *Vertebrate* type, in the formation of the chief nervous centres, and in the development of the notochord, are discernible at an early period in the life of the embryo. Another and final feature of developmental interest, consists in the presence, in the embryonic stages of every *Vertebrate*, of a series of openings or clefts, borne on the sides of the mouth, and known as the "visceral clefts" or "arches." These, in the case of fishes and some amphibia, retain throughout life somewhat of their embryonic nature, and bear the "branchiæ" or "gills;" whilst in all other vertebrates they become obliterated, and thus subserve no function or purpose in the life of these higher forms. Their universal occurrence, as embryonic structures in all *Vertebrata* thus forms a feature worthy of mention in defining the type. Various systems of classification of this important sub-kingdom have been proposed, but it may suffice, in the present instance, to simply enumerate the classes into which the Vertebrata, by common consent, are divided.

Table of the Divisions of VERTEBRATA.

CLASS 1. *Pisces* or Fishes. ,, 2. *Amphibia*—Frogs, etc.	Breathe by gills alone; or by gills in combination with lungs.
,, 3. *Reptilia*—Reptiles. ,, 4. *Aves*—Birds. ,, 5. *Mammalia*—Mammals.	Never breathe by gills, but by lungs exclusively.

It may be further remarked that the enumeration of the characters of these great "Morphological Types" will, if correctly appreciated, aid us in a great degree to the proper understanding of many important and subsequent questions, but chiefly that of the modern system of zoological classification, in which, as already remarked, these morphological types, under the name of "sub-kingdoms," figure as the great primary groups into which the entire animal series is divided.

CHAPTER VI.

Differences and Relations between Parts and Organs—"Homology" and "Analogy"—Definition of Homology, and Illustrations of "Homologues"—Modes of Investigating Homologies—Serial and Lateral Homology—Analogy—Definition—Examples of "Analogues"—"Balancing of Organs"—Correlation of Growth and Structure—Homomorphism—Mimicry—Symmetry of Animal Forms—Relations of Symmetry and Homology.

TURNING his attention to the more intimate relations which exist between different animal or vegetable forms, the naturalist seeks to establish certain principles subsidiary to those broader ones we have just been considering, and by means of which he investigates the relation between parts or organs in the same organism, or between parts and organs situated in different organisms. In the consideration of these latter distinctions we narrow the circle of our research, and now confine our attention to what might appropriately enough be termed peculiarities of structure and function in individuals or groups of individuals. The broad principles established by the study of morphology and physiology suffice to enable us to generalise. We still require aids of more particular application, which will assist us in our more detailed examination of the constituent groups into which the respective sub-kingdoms may be divided, or of those forms or individuals of which such groups are composed.

The chief subsidiary principles which are derived from morphology and physiology, are known respectively as "homology" and "analogy." We shall therefore consider these two points in the first place, and thereafter briefly notice several features which may be said to depend upon or take origin from them.

By "Homology" we express the relationship or connection between organs, parts, or structures, which are constructed on the same fundamental plan, or according to the same primary type; whether these organs be situated in the same animal or in different animals. Two organs exhibiting this relationship are accordingly said to be "homologous," or they may be termed "homologues." And the relationship or connection so expressed is at once seen to be of a *morphological* kind, since two organs to be "homologous" must be identical in "structure;" or, more correctly speaking, they must be identical in the fundamental or primary structure. We have thus, in the present instance, nothing whatever to do with the *functions* of such parts or organs. The "homologue" possesses a morphological value only, and has no kinship, other than an accidental one, with any physiological or *functional* relations. Identity or agreement in fundamental structure being the sole and principal characteristic of homology, we are prepared to admit, from the mere verbal significance of the word "fundamental," that homologous organs or parts may present variation in form; and that in some cases to a very considerable extent. Indeed it is the recognition of these variations which has chiefly prompted the work of tracing homologies, and caused the necessity for the establishment of some such sure clue, in disentangling and unravelling the tangled skein into which animal and plant structures are sometimes wound.

A very superficial consideration of the structural relations of animal forms will bring to light many prominent examples of "homology." Primarily indeed the members of any one of the great "morphological types" may be said to present among themselves a broad homological series, but it is the more suitable and peculiar province of homology to trace the structural relations between individual members of the type, and to thus narrow the broader limits and extend the more intimate details of its working. As very obvious and patent examples of "homologous" organs or "homologues," we may select the arm of man, the wing of the bird, the fore-limb of the horse, ox, or dog,

the paddle of the whale, and the "pectoral" or breast-fin" of the fish. All these members are identical in structure. A very cursory examination would show that the fundamental parts are the same in each; subject to variations in form and number perhaps, but leaving no doubt in the mind that one structural plan pervades them all. In the arm of man (Fig. 18, A) the following

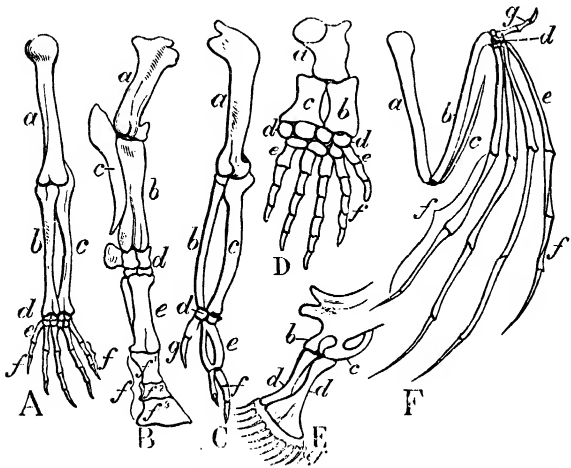


Fig. 18. ILLUSTRATIONS OF HOMOLOGY.

A, Skeleton of the arm of man: *a*, humerus; *b*, radius; *c*, ulna; *d*, carpus or "wrist;" *e*, metacarpus or "palm;" *f*, phalanges or bones of fingers. B, Bones of the fore-leg of the horse: f_1, greater pastern bone; f^2, lesser pastern-bone; f^3, coffin-bone. C, Skeleton of the wing of a bird; *g*, rudimentary thumb. D, Bones of the paddle or anterior extremity of whale. E, Skeleton of the "pectoral" or "breast-fin" of fish. F, Skeleton of fore-limb or wing of bat: *g*, rudimentary thumb. (The letters refer to the same parts as in the first figure.)

parts are found. Firstly, a single bone, the "humerus" (*a*), forming the upper arm; then two bones, "radius" (*b*) and "ulna" (*c*), forming the forearm; next, a series of small bones (*d*) disposed in two rows, and forming the "carpus" or "wrist;" then another series, forming the

palm of the hand, or "metacarpus" (*e*); and lastly, a terminal series, known as the "phalanges" or "fingers" (*f*).

Examine now the skeletal elements of the fore-limb of the horse, ox, or dog; that of the first-mentioned animal (Fig. 18, B) being probably the example best suited to our present purpose. We have no difficulty in at once recognising the "humerus" (*a*), and the two bones of the "forearm" (*b c*) are still present; but we observe how in the horse the radius (*b*) almost entirely forms this portion of the limb, and how the "ulna" (*c*) so distinct in man, has dwindled away to a mere fragment of the size to which we might expect it to attain. Then succeed the bones of the "carpus" (*d*); but we notice in the disposition of the "metacarpus" (*e*) and "phalanges" (*f*) a wide variation from the arrangement observed in the human subject. On close examination we find that only four metacarpal bones are represented in the horse. The first two represent those which in man support the ring and middle fingers, and these in the horse are united to form the single "shank" or "cannon-bone" (*e*). Then we observe the metacarpal bone of the little finger, forming a mere splint-like appendage of its larger neighbour, the "cannon-bone;" and lastly, the metacarpal bone of the fore-finger is represented by an attenuated piece, also applied closely to the "cannon-bone." The metacarpus has therefore in the present case undergone a very considerable modification, but not so great as to render our identification of its separate elements a matter of extreme difficulty. Next succeed the bones of the fingers or "phalanges" (*f*), and in these latter parts still greater modification is met with. A single finger only—the third—is represented in the fore-foot of the horse, and this solitary digit consists of three "phalanges" or pieces. The first phalanx or piece is composed of two phalanges united together, and in the horse this is named the "great pastern" or "fetter" bone (f^1). The second piece, or middle phalanx of the finger, is known as the "lesser pastern" or "coronary bone" (f^2); whilst the last phalanx or joint of the finger (f^3) is of expanded

and crescentic shape, and is known as the "coffin-bone." In the fore-limb of the horse, therefore, we are presented with a series of deviations from the human type of structure; yet we have no difficulty in at once determining that both of these members are constructed on the same type or plan, and they are therefore "homologous" in the truest sense of the word.

It would be needless to follow out in detail the other examples we have selected to illustrate the principle of homology. A glance at the illustration, and an examination of the corresponding parts in each member, will demonstrate the adherence to the primary type amid even great modification or alteration of structure. Thus, in the wing of the bird (Fig. 18, C), the humerus (*a*), radius (*b*), and ulna (*c*), are readily recognised; the distinct carpal bones (*d*) are two in number only; three metacarpals (*e*) exist—two being united at their extremities, whilst the third is distinct: and the fingers (*f*) number three in all—two being fingers, and the third a small rudimentary thumb (*g*). Here the fundamental structure, seen in the arm of man, still prevails throughout.

Similarly, in the paddle of the whale (Fig. 18, D), or in the bat's wing (F), where we have the humerus (*a*) distinct, the radius and ulna (*b c*) are readily recognised, and there is no difficulty in distinguishing the "carpus" (*d*), "metacarpus" (*e*), and "phalanges" (*f*). Or, lastly, in the pectoral or breast fin of the fish (Fig. 18, E) we can still trace the homology of the limb. The humerus is generally rudimentary, or may be wanting; the radius and ulna (*b c*) are usually to be distinguished; the carpal bones (*d*) vary greatly in number; whilst there is little difficulty in regarding the "fin-rays" (*e f*), as representing the "metacarpus" and "phalanges" of higher forms.

In the tracing of homologies there are three chief modes which may be either singly or conjointly pursued. The first and simplest of these modes consists in the *direct examination* and comparison of the organs between which we seek to find homologies. Then, secondly, if this mode of examination fail to afford us the desired

result, we may trace the *development* of such organs or structures, and observe whether they may not exhibit, in their earlier stages of growth, that resemblance and relationship which, in their mature state, and from alterations in the progress of development, we fail to find. Or lastly, we may require to trace the organ through the examination of a long series of forms, and seek in these latter to find *successive stages of alteration and change*, by means of which we may connect the aberrant and altered structure with that of the more typical and readily recognised organ or part.

Very briefly let us exemplify each of these modes of pursuing this most important inquiry. The comparison of the fore-limbs of the mammal, bird, and fish, illustrates the first mode of procedure. A simple examination and comparison served, without further investigation, to convince us of the homological relationship which existed between them.

The second mode of investigating the homologies of organs is opened to us by the study of development; that is, by watching the growth of the organism, and observing if, in its earlier form, it presents us with a community of type and structure from which the modifications which puzzle us are afterwards evolved. The bodies of many of the higher *Annulosa* present us with very familiar and excellent illustrations of this second mode of conducting our homological inquiries. Take the lobster as an example, and try to trace the homologies of the various segments of which its body is composed. We can readily demonstrate that all the segments of the lobster's body, and the appendages of these segments, without exception, are constructed on an exactly similar plan, or are, in other words "homologous." If we examine one of the segments of the tail, we find it readily divisible into a "body" and "appendages." The "body" of each segment consists of a ring-like structure, bearing two appendages, and each of these latter is composed of a little stalk carrying two flattened oar-like pieces. This simple structure is partaken of by all the joints forming the

abdomen or tail of the lobster; the last segment of all exhibiting a flattening and expansion of its appendages, but being otherwise readily reconcilable to the typical structure of the neighbouring joints.

The front part of the body, however, presents us with a totally different structural aspect from that we have been investigating in the tail. The head and chest of the lobster are massed together, and the various segments composing these regions are so united as apparently to defy recognition or correspondence with the structure of the tail-segments. Yet if we with care dissect out and separate the united parts, we shall find that not only are the segments which enter into the formation of the head and chest conformable to the typical plan of structure, but all the "appendages" of these segments similarly exhibit the same identity of structure. We can thus demonstrate that even the eyes, antennæ, or "feelers," the greater and lesser pairs of jaws; the foot-jaws; and the ordinary legs of the creature, are constructed on the same uniform plan, or are all "homologous" organs. Thus then we learn the important fact that each of the twenty-one segments of the lobster's body belongs to a common structural plan; and that the appendages, however diversified in function, are also entirely homologous.

Now we have here an example, not only of how the progress of development teaches us the homology of parts, but also of how it demonstrates and proves what a simple examination reveals. If we watch the development of the lobster, or of any typical member of its class, we find that after the segmented nature of the body has become apparent, the appendages are developed; those of the front portion of the body preceding the posterior segments in the order of development. But more important for our present purpose is the fact that all the appendages at first present a common plan of structure. Each consists, primarily, of the essential parts which we see in the tail-segments of the full-grown lobster, the subsequent phases of development tending to modify the anterior segments and their appendages in a great degree, whilst the posterior or hinder segments exhibit but a very slight

alteration from the primary and embryonic type. In other words, all the varied segments and appendages of the lobster—eyes, feelers, jaws, legs, and sw .nerets—are merely modifications of a common str .ral plan; in their embryonic condition they are all e..actly similar to each other. How has development assisted us here? It has shown us that the nature of homologies is in truth far more intricate and more closely bound up with the nature of the organism than at first sight we might think; and it also tends to impress the fact, with which we commenced our latter considerations—namely, that if we fail to trace the homology of organs and parts in the animal as a fully-formed being, we will readily and satisfactorily observe the community of structure in the embryonic form.

Lastly, it may be found the most convenient mode of investigating this subject, to trace the modifications of an organ, or series of organs, through a succession of forms, noting the various stages through which the organ passes in its way to become more typical, or, on the other hand, to deviate more widely from the original and recognised plan. We find in the swimming or air-bladder of the fish an excellent example of the manner in which this last mode of examination may be pursued. This organ is of very general presence throughout the class of fishes, and exists in the form least reconcilable with its homological relationship as a bladder-like body, filled with atmospheric air or certain gases, and situated beneath the spine of the fish. Its function is that of altering the specific gravity of the fish, and, by rendering the animal heavier or lighter, enabling it to sink or rise in the water. Now this swimming-bladder is homologous with the lungs of the Mammal or higher Vertebrate, and at first sight no two structures can be conceived which are more unlike to each other than these. The present, therefore, is a case in which we determine the homologies of the organ by tracing it throughout the group, and by following it through its variations and development, until we perceive its relationship with the typical organ to which we have asserted it is allied.

The air-bladder is by no means universal in its occurrence throughout the group of fishes. Indeed some fishes, to which it would appear to be of most service, are destitute of it; whilst others which possess it could apparently, in their habits and mode of life, dispense with its presence. Yet this at first sight inexplicable fact, is at once explained by the consideration that we are not dealing with any mere empirical law, but with a deep-seated principle, in which mere exceptional instances of occurrence or absence of structures are of little moment or import, in the face of an ulterior scheme of progress towards unity of type or plan.

We start in our homological journey with the simple closed air-bladder of many fishes. The first step perceptible in the direction of the lung is the presence in some fishes of a duct or tube leading from the air-bladder, and opening at the upper and back part of the throat of the fish. This "pneumatic duct," as it is called, is soon perceived to be the early representative of the "trachea" or windpipe of the higher vertebrate; and we note this fact, not only from its position as regards the gullet, but from the possession by certain fishes of a rudimentary larynx or organ of voice. Already the examination of forms is assisting our tracing of homology, and we have now advanced from the shut and closed sac to a structure not only exhibiting divisions of its substance imitative of the double nature of lungs, but also provided with a "trachea" or windpipe, and a larynx in a rudimentary state of development.

A further stage shows us forms in which not only the external division of the air-bladder undergoes an advance, but where its internal surface becomes essentially of lung-like structure, and where the vascular arrangements also partake of the nature of those seen in the true lung. And so we latterly find the swimming-bladder actually transformed into a lung, and performing, in the economy of certain forms, all the functions which pertain to that higher type of respiratory organ. This latter mode of tracing homologies will be found in practice one of the

which is applicable to only the superficial conditions of an organism, and which does not at all suffice to explain, or, indeed, agree with, the internal disposition of organs or parts. For although an animal may appear "bilaterally symmetrical" when viewed externally, yet its internal symmetry, or the arrangement of its internal parts, may not, and generally does not, present a similar and homologous arrangement. And when we further reflect that, in a body exhibiting externally this "lateral homology," we may find organs single in nature, and disposed to one side more than to the other, it becomes evident that the theory upon which the existence of a "lateral homology" is based, is not of an unquestionable or satisfactory kind. Then the theory is also insufficient to account for or explain the conditions in virtue of which certain deep-seated and normally symmetrical organs become asymmetrical. Why it is, for example, that one lung becomes shrivelled up, abortive, and functionally useless in most snakes, or that the right ovary and oviduct of birds is generally wanting or rudimentary, we cannot tell; nor is the presumption of Mr. Spencer's "external conditions" at all adequate to explain the cause of such phenomena. Or even, in the case of external appendages, such as the great "chelæ" or claws of the lobster and hermit-crab, where we observe that one claw is developed to a greater extent than the other, the theory cannot be said to render the cause of this asymmetrical and superficial condition plain or apparent.

Hence, although the term "bilateral symmetry" may be conveniently used to express a superficial character in the external form of animal organisms, it cannot be held to apply to the conditions or arrangement of deep-seated structures. And so far from the "external conditions" of the evolutionist being proved to be the *cause* of the "lateral homology" seen in any organism or organisms, the mere sequence between the homology and such conditions has not been made plain. It appears much more probable that the symmetrical disposition of superficial or deep-seated organs, or, on the other hand, their asym-

metrical aspects, are subject to laws similar or analogous to those which regulate the growth and development of the organism as a whole. At the same time we must, of course, hold Mr. Spencer's theory in connection with the views and ideas, which, as a believer in the evolution of new forms from pre-existing species, he promulgates and supports.

We have dwelt thus at considerable length on the question of Homology, and its use in the differentiation of animal structures and forms. We must note carefully, in the first instance, that the aim of homology is to demonstrate the structural identity of parts or organs, which are constructed on a common fundamental plan. Then, secondly, that homology is traced and exists independently of the *functions* or uses of such organs, as we shall presently observe. And, lastly, that we may trace homologies between the parts of different animals, or between the parts of the same animal. The former aspect of the science we may term "common" homology, whilst the latter we may designate "individual" homology. Of this last-mentioned division "serial" homology is a branch; and further research may add to the modes by which we may in the future be enabled to investigate the relations between parts or structures in the individual organism.

Although of subsidiary importance when considered in relation to homology, it is at the same time essential that we have correct notions of "Analogy." Homology we know to mean identity in fundamental structure. "Analogy" we may define as identity in *function*. We thus observe that whilst homology expressed a morphological distinction, analogy expresses a *physiological* one. Two organs, to be "analogous," must therefore perform a similar function in the economy of the organism or organisms in which they are situated. It is not at all essential to a correspondence of analogies that their *structure* should be similar. In other words, homology may exist without analogy; or, *vice versa*, two organs may be analogous without of necessity being also homologous. At the same time, and although these conditions are entirely

independent of each other, we may find organs to be in themselves both homologous and analogous. They correspond in the latter case, both in fundamental structure and in function.

As examples of analogous organs, we may select the wing of the bird and that of the butterfly. Both possess the same function—that of serving as organs of flight. They are, however, purely analogous, in that they have no homological relations whatever. The structure of the one entirely differs from that of the other. Similarly, there is no homological identity between the jaw of a lobster or insect and that of a mammal. The former is merely a modified limb, whilst the latter consists of a distinctly developed part of the head. Yet the two organs are distinctly analogous, in that they both perform the same function, namely, that of the prehension and mastication of food.

Then, lastly, and as examples of cases in which the homology and analogy of two organs correspond, we may select the wing of the bird (Fig. 18, *C*), and that of the bat (Fig. 18, *F*); or the paddle of the whale, and the "pectoral" or "breast-fin" of the fish. If we examine the fore-limb of the bat, we shall find it to be structurally identical with that of the bird. The only notable difference, indeed, is in the immense elongation of all the digits of the hand (*e f*), save the thumb (*g*), and in the number of the digits. But both organs are entirely "homologous;" and they are also analogous in that they are used for the same purpose—that of supporting their respective possessors in the aërial medium. The paddle of the whale and the pectoral fin of the fish, are also both analogous and homologous. The same fundamental elements of structure enter into the composition of both, and their functions are also similar in every respect.

Recognising the relations and deductions to be drawn from a study of homologies and analogies, we are prepared to admit the great value of these relations in the philosophic study of living beings. Indeed, without the guiding aid of these principles, the naturalist's task in classi-

fying and arranging the varied forms with which he has to deal, would become an almost insurmountable labour and difficulty. Yet, calling to his aid the generalisations in which the study of Homology and Analogy result, he is enabled to unravel the mysteries in which similarity of appearance shrouds the real nature of organisms considered singly or in groups. And below this superficial consideration lies the deeper and more complicated task of tracing out unities of plan and structure and type through endless forms of variation and modification—a labour to be ranked among the most important of those which the biologist has given him to do, and in which the value of all his modes of investigation is surely tested and tried. It is in such a task that the deductions of true homology and analogy prove of the utmost service and avail.

And, lastly, the thorough investigation of these principles is the best corrective to those very popular, but at the same time very erroneous notions, that animals or their organs were specially created to fulfil special ends. That this doctrine of the "final causation" of living beings,—resulting in the discovery of "special" and often misconstrued uses of animal and plant forms,—is the *ultimatum* of biological investigations, few who correctly appreciate the deductions of homology will allow. The entire organisation of nature in truth reveals a grand unity of type and plan, regulated by well-defined laws, and not a mere collection of scattered shifts and expedients, designed to fulfil as many incongruous and petty ends.

The present seems the most fitting opportunity for saying a few words regarding several points allied in nature to the questions in the study of which we have just been engaged.

These latter points are included under the respective terms of "*Balancing of Organs*," "*Correlation of Growth*," "*Homomorphism*," and "*Mimicry*."

By the term "Balancing of Organs," is meant the principle, insisted on by some authorities, "that excess of development in one organ or part is frequently accom-

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panied by a corresponding or proportional deficiency in a neighbouring or connected organ." And by means of this principle it has been attempted to account for numerous deficiencies in structures and parts, which deficiencies do not appear to admit of easy or ready explanation according to the ordinary laws of growth. The considerations which militate against the adoption of the principle thus laid down, are similar to those already enumerated when treating of "Lateral Homology." And the fact that such excess of development in one organ is not invariably accompanied by atrophy or deficiency of another organ, leaves the supporter of the principle in the twofold dilemma of endeavouring to account for cases in which the deficiency occurs, and also for those cases in which no such deficiency is present. Then, in such cases as those exemplified by the absence of the one ovary and oviduct of birds, the principle of the "balancing of organs" does not explain the cause or conditions on which such non-development depends, any more than it can account for the reason why the other oviduct should persistently be developed, and retain its normal size, structure, and functions.

We must, however, carefully distinguish between excesses, or want of development, in a pathological or diseased state, and those which exist irrespectively of states of altered or abnormal nutrition. The connection between an obstructed or diseased circulation, and an enlarged or diminished size of the heart, for example, are referable to the ascertained relations of cause and effect. But in the absence of diseased states it is impossible in the same way to account for the results which the principle of the "balancing of organs" seeks to explain.

Several points of curious interest are included in the consideration of the term "Correlation of Growth," or "Correlation of Forms." By this term we express the fact of certain organs, parts, or structures, not necessarily related to each other by structural, or even functional, peculiarities, being invariabiy found to co-exist or to be associated with one another. In other words, these

organs or parts are invariably co-existent, irrespective of their differences in nature. Thus all animals which suckle their young, or are provided with mammary glands, invariably possess two "condyles," or articular processes of characteristic structure, on the occipital bone of the skull, and also possess non-nucleated red blood-corpuscles. Or again, we find that "rumination," or the power of "chewing the cud," is invariably associated with a cloven or cleft condition of the feet. And many other instances might be offered as illustrations of this curious fact.

Regarding the essential nature and cause of these correlations of growth or structure, we know absolutely nothing. The facts, upon which this principle is built up, have been simply ascertained from a careful examination and comparison of forms, and we can only limit ourselves to a plain statement of these facts. Morphological science does not warrant us in seeking to establish "a causal relationship between the organs thus associated together." And although theory and hypothesis are not wanting, by means of which the relations between the cause and result of this "correlation" are sought to be explained, yet there are few who, recognising the plain path of inquiry, will be tempted from that path by a theory obviously moulded to the facts, and so unworthy of our support or countenance. It is more consistent with a true scientific spirit to own our inability to explain this correlation, and simply to recognise this co-existence of structures, than to seek a convenient explanatory bye-road which the higher knowledge of to-morrow may close.

We therefore are forced to content ourselves with the simple recognition of the facts included under the term "correlation of growth," and at the same time we own the mere empirical nature of the law. It is one deduced solely from observation and experiment, but at the same time it would appear to be dependent on other than merely accidental causes.

As subsidiary to the more typical condition of "cor-

relative" structures, it may not be out of place to remind the reader of the presence of a certain amount of "sympathy" between certain organs in the animal economy; these latter organs, however, being connected together, often forming part of one system, and being otherwise bound to each other by relationships evinced through the medium of the nervous system. Such instances of "sympathy" are well known to the medical world; and as an example of these, the intimate "sympathy" between the reproductive organs and the breasts or "mammæ" may be cited. Such conditions, occurring in instances admitting of obvious explanation, may be regarded, and rightly so, as falling without the boundaries of the considerations we have just been noting; but they serve, at the same time, to show the presence of "correlation," manifested in a great degree between organs of the same economy.

But quite as important a consideration lies in the fact that the apparently constant nature of the law of correlation is of the greatest possible service in determining the relations of animals in the past, and in settling their affinities with forms now existent. We know, for example, that all mammals possess the certain and distinctive features before mentioned, and that these, in virtue of the law of correlation, are invariably associated. Hence if we ascertain the presence of one of these features, we can safely affirm the existence of all the others. Thus, if we know an animal possesses two occipital condyles of a certain structure, we may predict that it will also possess non-nucleated red blood-corpuscles and mammary glands. And in the researches of the palæontologist, employing as he does the inductive method of reasoning, by means of which he argues of the unknown from his knowledge of the known, or argues "respecting a whole class what has been ascertained respecting one or more individuals of that class," this unvarying nature of the "law of correlation" assists him in framing, from a part or possession of one character, a correct generalisation regarding the whole.

This law, it is however to be borne in mind, is subject

to the conditions and fate of all merely empirical generalisations; that is, it *may* be proved erroneous by subsequent observation or experiment. Whilst, therefore, we are fully entitled to found our belief on the constant results of experience, we must at the same time be prepared to have our conclusions tested, or even set aside, by the progressive march of inquiry, and in the light of new truths which further observation may disclose. Huxley sums up the matter very succinctly when he says — "Not that it is to be supposed that the correlations of structure expressed by these empirical laws are in any sense accidental, or other than links in the general chain of causes and effects. Doubtless there is some very good reason why the characteristic occiput of a Mammal should be found in association with mammæ and non-nucleated blood-corpuscles; but it is one thing to admit the causal connection of these phenomena with one another, or with some third; and another thing to affirm that we have any knowledge of that causal connection, or that physiological science, in its present state, furnishes us with any means of reasoning from the one to the other."

The term *Homomorphism* has been applied to indicate a series of resemblances, traceable between organisms which are themselves far removed from one another in structure and organisation. Examples of this "homomorphic" resemblance are seen in the close likeness between some of the *Hydrozoa* or Zoophytes (Fig. 4), and the *Polyzoa* or "Sea-mat" class (Fig. 6). And similar resemblances may be traced between the *Infusoria* and *Rotifera*. Such a resemblance is, in itself, an apparently trivial matter, seeing that the structural affinities of such organisms are usually and widely different. But modern theories profess to see an ulterior and deeper meaning in such resemblances—firstly, in that such forms may take the place and functions of one another; and secondly, in respect of their origin, in that certain "conditions" are supposed to have affected, in a greater or less degree, the resemblances which they bear to each other.

A survey of the geographical distribution of animals

and plants, furnishes us with many examples of certain so-called "representative" or "homomorphic" forms, taking on themselves, in a particular area, the place and functions of those forms to which they bear a resemblance. But this is not always the case, and so far from being widely separated from each other, we may find "homomorphic" forms living side by side. The tendency of a section of modern thought would seem to be that of regarding such forms as springing primitively from a common origin, and that, under certain conditions, changes in organisation took place, affecting their structure and relations, but leaving their external configuration comparatively unaltered. The older theory of Forbes advocates the idea of special creations in special centres; the conditions surrounding each organism or group being nearly or exactly similar, and producing structures of close identity in appearance and form. Neither view appears wholly adequate to explain all the circumstances; but of the two, the latter has the merit of being supported in some degree by facts as they stand.

Mimicry is the name given to those conditions in virtue of which an animal form assumes the outward characters and appearance of another animal form, or of a plant, or even of some lifeless or inorganic object; these resemblances being destitute of any connection with the position or structural relations of the animal. Such conditions appear to be in some degree explained by the supposition that they are assumed for the purposes of defence or protection against enemies. The observations of Messrs. Bates and Wallace on the subject of "mimicry," form the chief sources from which our information regarding these curious conditions has been derived. Throughout the class *Insecta*, we find instances of "mimicry" of most frequent occurrence; and the accounts given by the observers just mentioned, of the circumstances under which the mimetic resemblances are assumed, will be found exceedingly interesting, and worthy of perusal. The mere mention of a few examples of this peculiarity will suffice in the present instance. We thus find that

among the *Orthopterous* insects, the so-called "walking leaves" or *Phylliidæ*, possess wings, in which not only the texture, but also the colours and shades of leaves are exactly imitated; so that these insects could not, without very minute examination, be detected among leaves, the appearance of which they so accurately mimic. Similarly the *Phasmidæ* or "walking-stick" insects, also included among the *Orthoptera*, present us with perfect resemblances of the dried twigs of trees. And in other cases we find that even the parasitic fungi which grow upon leaves, are, in the case of certain tropical butterflies, most naturally reproduced in the mimicry; and the delusion, if one may so term it, is thus rendered the more apparent and real.

Of these mimetic phenomena we have as yet had no explanation which can be considered wholly free from being enlisted under the banner of some special theory, and so in some degree made subservient to the ends and ulterior purposes of the theorist. We may, at any rate, and without looking at the deeper causes of the condition, assume that it is, in all probability, made subservient, if not specially adapted, to the defensive requirements of the creatures in whose economy it is exhibited.

The term *Symmetry* so frequently occurs in discussing the relations of animal and plant forms, that it may be well, in concluding the present chapter, to briefly indicate the meaning and import of the term. By "symmetry," used in the common acceptation of the term, we mean the form or arrangement of parts of any particular object or organism. And, as applied technically to the parts or structures of an organism, or to the organism as a whole, we indicate by its "symmetry" the apt and similar arrangement of its "elements of form." Viewed thus, and apart from its subsidiary meanings, we speak of animals or plants possessing certain kinds of symmetry, and we thereby express the particular arrangement of those elementary parts, of which a philosophic morphology may conceive their bodies to be composed. For convenience sake the morphologist invents or supposes

the existence of a purely ideal "element of form," to which the term "merosome" has been applied; and the particular kind or kinds of symmetry characteristic of any form are viewed as the result of the regular and defined "repetition of the same element of form."

Three kinds of symmetry, or modes of disposition of the primary elements of form or "merosomes," may be enunciated, and we have already had occasion, in discussing the characters of the great "morphological types," to refer to these varieties of form. Thus, we have firstly *Bilateral* or "two-sided" symmetry, in which the elements of form are equally disposed on each side of the middle line or mesial plane of the body: in other words, the body, which is bilaterally symmetrical, can be divided into equal right and left halves. The second kind of symmetry is termed *Radial*: and in this variety we find the "merosomes" disposed radially around a central point or axis. Whilst in *Zonal* symmetry the elements of form are arranged in "zones" or segments, one after the other, in a horizontal or longitudinal axis.

Examples of these various dispositions of form will be readily suggested from a cursory consideration and review of the characteristic features of the "types." Thus the *Vertebrata* and *Annulosa* each exemplify the "bilateral" and "zonal" symmetries—that is, we find that the body of every vertebrate and of every annulose animal can be divided through the mesial plane into equal halves, and we further notice the "zonal" symmetry in the arrangement of the segments of the vertebrate spine, and in the disposition of the joints or "zones" in the body of the annulose animal. The "radial" symmetry is typically seen in the *Annuloida*; where, in the body of such a form as a sea-urchin or star-fish, the radial disposition of parts can be readily perceived.

The relationship between symmetry and homology will be sufficiently apparent. Symmetry is a homology of a superficial kind, or of external surfaces. We may in many instances find that symmetrical parts are also homologous; but the two conditions, viewed simply, and without their

connection with any theoretical considerations, are perfectly and naturally distinct. The "external conditions" of Spencer, would, on the contrary, seek to establish a definite connection, not only between mere symmetry of external form, and the deeper symmetry we term "homology," but also between the causes which give rise to each. Such causes are said to be those affecting the organism and its descendants from without; or through the operation of conditions which are external to the organism. We have already seen how these external causes are incompetent to give rise to such conditions; and how, in all probability, the conditions are at once deep-seated, internal, and intimately bound up with the laws regulating the inner life and economy of the form.

CHAPTER VII.

Classification ; Nature and mode of—"Natural" and "Artificial" systems—Morphology and Physiology the two factors of Classification—System and Mode of Arrangement of the Animal Series : the Type or Sub-Kingdom ; Class ; Order ; Family ; Genus—Species—Nature of "Species"—Variation in Species—Recent Opinions regarding the significance of the term—Provisional Definition of "Species"—Illustrations of Classification.

THE introductory matter which has formed the subject of the preceding chapters prefaces, in a very convenient manner, the important section, upon the consideration of which we now enter. The ultimate aim of the principles of biological science, and of the recognition of those relations which exist between living forms, is the due arrangement of these forms in a certain system, and according to a scientific mode. Such a system of arrangement we denominate "classification ;" and this latter, in turn, is a necessary preliminary to the systematic and careful examination of individual organisms, or groups of organisms.

The early history of almost every science may be said to begin with a scheme of classification. The beginnings of a scientific method will generally be found to have taken origin in a rude attempt to arrange the objects or subjects of which the method proposes to treat. As might be expected, such initiatory attempts at systematic arrangement present us with very varied aspects, so far, at least, as the features from which the principles of the classification were drawn are concerned. These features are found to be essentially those derived from external configuration, or from characters which a mere superficial examination might furnish. And the characters thus

ascertained result in the formation of a so-called "artificial" system of classification; since in its construction the deeper and more reliable features of structure are neglected for the "artificial" characters drawn from chance resemblance or configuration. A system of classification, on the other hand, founded on the characters furnished by a consideration of the entire *structure* of the organisms it is proposed to classify, and which system accordingly includes all the natural details of form, is in contradistinction termed a "natural" classification.

No great amount of thought is needed to perceive that the earlier classifications were eminently "artificial" in character; and such systems find their existing prototype in the arrangement which we might suppose a savage to make of the living things by which he is surrounded. Thus he would classify together birds and bats, from the fact that both indulge in the habit of flight. The whale he would classify with fishes, because it resembles them in external appearance and habits. And he would group frogs, newts, lizards, and snakes together under the term Reptiles, thereby including under this single term an immense variety of heterogeneous forms. And, finally, if we can suppose sufficient intelligence to guide the savage in his work, he would tend to arrange the animal kingdom in a linear series, to form an unbroken and continuous line of beings, commencing in detail with the lowest organisms, and capping his series with the highest form. Now in each case the primitive taxonomist has seized on purely external characters and resemblances; and as a result he has formed certain "artificial" groups, including individuals which may have, save perhaps in form or habits, no community of type and no "natural" affinities.

Conversely, let us suppose the scientific taxonomist, with the knowledge which he has derived from his study of Morphology and Physiology, to be placed in the position of the primitive savage. His mode of classification would be essentially and exactly opposite to that of the latter. He would, by a thorough investiga-

tion of the structure and functions of the various forms he might meet with, first demonstrate the existence of distinct types or plans of structure; and he would thus construct great primary groups, into which the entire series would be divided. Fixing definitely the characters of these primary groups, he would be enabled to refer to them any subsequent forms which might fall under his notice; and then his further labours would consist in the assorting and parcelling out of his primary groups into subordinate divisions. And, so far from his system partaking of the nature of a linear or continuous series, he would find that the construction of any such arrangement would be unnatural and impossible; since in his labours he would demonstrate that there are forms of essentially different nature, which it would be impossible to arrange one above another in point of organisation, and that, in short, the very nature of the case does not admit of any such arrangement being made.

The labours of the primitive savage, therefore, exemplify for us the formation of an "artificial" arrangement of the organic series. The labours of the scientific morphologist show us on what principles we construct a "natural" classification, which thus brings together organisms or groups of organisms allied to each other by all the essential points of structure. This latter, as we shall have occasion to observe, is the only system which can be said to perfectly fulfil all the conditions required of a truly scientific arrangement.

To trace from the standpoint of a historian the progress of the system of classification from its rude outlines and imperfect details to its establishment upon a sure basis, is a task which, however interesting and instructive it might prove, falls without the boundaries of the present work. I have already sufficiently indicated the starting-point of such a history, and the student will find no difficulty in obtaining from appropriate sources an interesting sketch of the progress of this department of biological science.

A truly philosophical system of classification has been

defined as "an expression, in a convenient form, of the facts and laws of Morphology and Physiology." And the statement thus enunciated expresses the grand fact that it is from a correct appreciation and idea of the differences and relations which the study of structure and function reveals, that we are enabled to construct a truly "natural" system of classification of either animal or plant series. The full knowledge of structures and functions is therefore the sole aid which we require in the task of arranging either kingdom.

We have already seen that the ultimate object of all classification is the arrangement of objects or forms into defined groups, chiefly for the purposes of ready identification, and detailed examination of their structure and relations. This, shortly stated, is the aim of every system of arrangement, on whatever conditions or by whatever means the system may be constructed. We arrange or classify a library for the express purpose of enabling us to select and obtain, without trouble, any particular volume we wish to consult. And there are, it is obvious, many methods by which our end may be attained. We may arrange our books alphabetically, or we may assort them according to the subjects of which they treat, or we may even employ the characters afforded by size or appearance, to enable us to place them conveniently for access and purposes of consultation. And if we follow out a little further the simile of the library arrangement, we shall find that we may gain a general idea of the motives which, at various stages in the history of Biology, have prompted the scientific taxonomist in his labours.

The process of classifying books by size or appearance requires no great knowledge or methodical power. A person who could neither read nor write, but who possessed some idea of colour and size, might undertake to arrange the library at once tastefully and harmoniously; but, at the same time, such a classification would be entirely destitute of any literary value, and clearly of no service to any one unacquainted with the library. It would be, in short, of no universal or convenient application. Such a

process is imitated, then, in the earlier and artificial systems of the classification of animals and plants. Conspicuous characters may be said to constitute the basis of these earlier methods, just as it forms the basis in grouping together the books after this first method. Alphabetical classification, in the second place, whilst requiring a certain amount of knowledge, may yet be wholly inadequate to fulfil the ends of a perfect system of arrangement; and the superficial classifications which existed in such numbers in the later stages of the progress towards taxonomical perfection, very closely correspond to this latter arrangement of the library. Lastly, to classify our library according to the subject-matter of the volumes requires a great amount of knowledge and discrimination; but the result of this latter arrangement would be the assorting of the books in a manner corresponding in detail to that in which the principles of Morphology and Physiology serve to arrange the animal and vegetable series in the present day. Leaving superficial distinctions and artificial characters, we fix on the evidences of structural type and the degree of physiological perfection, as affording us the requisite power to marshal the varied forms of life into their natural places and rank in the scale of being.

Recognising the presence in the organisation of animal and plant forms of two great factors or principles —the morphological factor and the physiological factor —we are prepared to regard every animal or plant as depending for its place in the scheme of classification, firstly, upon the fundamental plan or type on which its body is constructed; and, secondly, on the degree of perfection to which the processes or functions of life are carried within the organism. And if, in addition to these primary facts, we consider the existence, in most instances, of the "law of correlation" of forms and structures, by means of which we ascertain the invariable co-existence of certain characters, we obtain a comprehensive, natural, and accurate synopsis of the form itself; and also of all forms with which the same modes of investigation prove our typical form to be related.

But, further, the "natural" system of classification takes into account not merely the present features of the organism as a fully-formed being. It also traces its life-history backwards by aid of development, and thus derives its special characters from a review, not of a mere part of its existence, but of its entire life-history.

Having thus gained an idea of the extent and aims of the subject before us, we may next observe how the foregoing principles are put to a practical use. Bringing before us as taxonomists the entire animal kingdom or series, we first look about us for certain broad and general features, by means of which we may parcel out our kingdom into definite districts, susceptible each of further subdivision. Such primary groups Morphology provides us with in the form of the six great "Morphological Types," which, as previously remarked, figure in the system of classification as "sub-kingdoms." These sub-kingdoms are based, as we have observed, on the existence of six distinct types or plans of fundamental structure recognisable in the animal world. Each sub-kingdom has thus an entity of its own, and the remembrance of this fact will serve to facilitate our appreciation of the difficulties, and indeed impossibilities, which lie in the way of the construction of a "linear system" of classification. These sub-kingdoms are divided into subordinate groups called "Classes;" the "Classes" are in turn subdivided into "Orders;" the "Orders" are broken up into "Families;" the "Families" into "Genera;" and the "Genera" into "Species."

We thus descend from a universal to a particular quantity. We begin with the entire kingdom, and at last arrive at those units of which the series in its entirety is composed. A tabular view of the system of classification might be rendered thus:—

KINGDOM divided into { SUB-KINGDOMS divided into { CLASSES divided into { ORDERS divided into { FAMILIES divided into { GENERA divided into { SPECIES

Let us next exemplify this process of progressive analysis in the scheme of classification. Having before us the entire animal series, we find that Morphology divides it for us into the six types. Each type includes a large number of forms, which agree in having their bodies built up on the same fundamental plan of structure. So far Morphology alone assists us. The division, so far as it has proceeded, is founded on purely structural grounds. We know, for example, that the Vertebrata are distinguished by the peculiar division of the body into two distinct regions, as we have already observed and illustrated (Figs. 16 and 17). Then we find subsidiary characters in the relative positions of the neural, hæmal, and digestive systems, in the presence of a notochord or vertebral column, and in other and minor structural features. All these characters belong to the Vertebrata as a *type*— that is, every member of the sub-kingdom *Vertebrata*, must agree with its fellow Vertebrates in the possession of the special features which are distinctive of them all.

But if we examine, even with a superficial glance, the various forms to which, in virtue of this community of type, the term *Vertebrate* may be applied, we at once detect very many and important modifications of the same structural plan; and a study of the more intimate homologies of the group, as also of the degree to which the "specialisation of functions" is carried out in the various Vertebrate economies which we may examine, serves to show us that the members of a type or sub-kingdom exhibit among themselves certain broad variations of the structural plan. These broad variations are determined by the degree of perfection in which the "specialisation of functions" exists; and the characters adduced from these latter considerations suffice to constitute large groups subsidiary to the sub-kingdoms, and known in our system of arrangement as "Classes."

As Professor Agassiz expresses it, classes are divisions which include forms built up on the same morphological type or plan, but exhibiting variations in the manner

according to which the plan is executed. This may be expressed in another way by saying that classes are groups of forms subsidiary to a morphological type, and which derive their special characters from physiological variations, and from the structural and "correlative" modifications dependent thereon.

A cursory examination of the *Vertebrata*, then, from a conjoint morphological and physiological standpoint, would result in the elimination of certain subsidiary groups or "classes." The first series of forms which we could differentiate would exhibit an adaptation to an aquatic existence. The limbs would appear in the form of fins; the breathing organs would be similarly modified to suit an aquatic life; the physiological perfection of the digestive and circulatory functions would be respectively noted; and in this way a "class," that of the *Pisces* or Fishes, would be formed, distinguished thus by a certain physiological status, and by a corresponding and special morphology. At once, therefore, we not only express the characters common to the members of any "class" or group, but also those characters by which it is distinguished from every other group. The statement of these characters, in fact, "constitutes the definition of the group."

Similarly, we can distinguish a second "class" evincing a higher degree of physiological specialisation than the preceding group; this latter "class" showing us a greater perfection of the skeleton; the presence of lungs in the adult in addition to the gills of early life; an advancement in the structure and functions of the heart; and a "metamorphosis," or certain series of changes, through which the young embryo passes in its progress towards adult and mature existence. These characters, expressing a functional state higher than that of the fishes, and necessitating a more perfect morphology, map out for us the "class" *Amphibia*.

The *Reptilia*, or Reptiles, forming the third class, lead us to a still higher degree of specialisation. The presence throughout life of lungs only; of a compound lower jaw and "quadrate bone;" of limbs (when present) suited

generally for terrestrial progression, and of other functional peculiarities, define the class before us.

Then the *Aves*, or Birds, are defined by their warm blood; the peculiar structure of their lungs; the character of the body-covering; the modification of the anterior limbs for flight; and by corresponding physiological characteristics. Whilst the *Mammalia* are known by their simple lower jaw; their two "occipital condyles;" their non-nucleated red blood-corpuscles; and by the possession of mammary glands.

The division of the *Vertebrate* type in this way, will suffice to exemplify the mode in which the physiological principle of "specialisation of functions" primarily aids us in subdividing a sub-kingdom. It must be borne in mind, however, that the morphological distinctions are not always subservient to or dependent upon the physiological ones. On the contrary, it is sometimes exceedingly difficult to detect any differences on physiological grounds, whilst the morphological conformation may at once assist us in distinguishing between forms, or, on the other hand, aid us in maintaining their relationship. And further, the "law of correlation of forms," which, as we have seen, lies at the foundation of many definitions, exists independently of any physiological differences. Whilst thus the presence of "correlative" structures forms the most stable element in many definitions, we are unable, as already observed, to trace any causal connection between the correlated organs or parts. Apart from these latter considerations, however, we must recognise the conjoint value of Morphology and Physiology in serving to determine the relations between any two organisms or groups of forms.

The next division which we notice is the "Order." This term is applied to those subsidiary groups into which the "class" is divided. In the differentiation of "orders" the morphological differences become less apparent, whilst the physiological ones become better defined than before. An "order" thus retains the morphological features of its "class," just as a "class" retains those of

its "type;" but the various "orders" of a "class" generally vary greatly in the degree of physiological perfection to which they may severally attain.

The "order" is divided into "Families." These latter divisions are not to be regarded of primary importance, and in most cases serve as convenient stepping-stones from the "orders" to the "genera," where the number of forms included in an "order" is very great.

The "Genera," into which the "family" or "order" is divided, bring us to the consideration of characters which very nearly approach those of the individual; and accordingly we find the circle of physiological distinctions growing gradually more contracted, until in the "species" we reach the characters which are specially distinctive of the *individual* organism, and which are accordingly more localised and susceptible of determination than those of the larger groups. "Species," in this view, and without prejudging the remarks to be presently made on the origin and limits of species, may therefore be held to be "the most limited group of individuals which can be defined and separated from all other groups by a common character."

The process of classification is therefore essentially one of differentiation, or of the separating out firstly of groups, and through the groups of the "specific" individual. With "species" we reach the unit of classification, or that quantity, from and through combinations of which the entire scheme of classification is made up. To obtain a satisfactory idea of the terms we have just examined, in reference to "species," it will be necessary to review them in an opposite order from that in which we have just been considering them. We shall therefore begin with the consideration of the term "species," which in more ways than one has been the bugbear of classification, and concerning the nature of which our ideas have, within the past few years, undergone a remarkable change.

In considering the nature of the term "species," and also the views regarding it which recent observations and theories have promulgated, it will be at once the easiest

and most satisfactory course, if we turn our attention, in the first instance, to the consideration of the opinions formerly held with regard to the limits and meaning of the term; then to the more modern views concerning species; and, incidentally, to a brief summary of the arguments *pro* and *con* the opposing doctrines.

At the outset of our inquiry we are led to consider a few of the many definitions which have been given of "species." A "species" has accordingly been defined by Forbes as "an assemblage of individuals presenting certain constant characters in common, and derived from one original protoplast or stock." Martin says that "species are distinct forms, originally created, and producing, by certain laws of generation, others like themselves." Cuvier defined species as "the collection of all the beings descended the one from the other, or from common parents; and of those which bear as close a resemblance to these as they bear to each other." Müller tells us that species "is a living form, represented by individual beings, which reappears in the product of generation with certain invariable characters, and is constantly reproduced by the generative act of similar individuals." Buffon maintains that "species is a constant succession of individuals similar to and capable of reproducing each other." De Candolle says that a "species" comprises "all those individuals which mutually bear to each other so close a resemblance as to allow of our supposing that they may have proceeded originally from a single being or a single pair." Woodward explains that a "species" is constituted by "all the specimens or individuals which are so much alike that we may reasonably believe them to have descended from a common stock." And, lastly, we find "species" by other writers to be defined as "an assemblage of individual animals which are supposed all to have descended from the same parents, and exhibit the closest resemblance in all parts of their structure;" or as "a number of animals so closely resembling each other that they all might be supposed to be the offspring of the same parents, and in turn

to give birth to progeny exactly resembling themselves."

Now, the list of definitions just cited, serves admirably to show the chief and essential ideas which the use of the term "species" involved at a period comparatively recent in the history of biology. And these points were, firstly, the recognition of a certain degree of "resemblance" between the forms of which a "species" was composed; and, secondly, a community of descent, or that the members of a species must have descended from a single pair, or from pairs of individuals of exactly similar nature. We thus see that the scientific term "species" is one which, according to the former views, might be adequately and correctly enough rendered by the commonplace word "kind." And accordingly the fact of two animals belonging to the same "kind," popularly speaking, necessitated, firstly, a close resemblance between them; and, secondly, the supposition that their progenitors were also similar to one another. Such were the ideas formerly involved in the use of the term "species;" and it will be well to bear these ideas in mind, in order that we may observe more clearly the nature of the sweeping changes which of late years have taken place in opinions regarding the limits and significance of the term.

But if we more carefully consider the foregoing definitions, or if we investigate the further opinions of naturalists in the past regarding "species," we find that they attached to "species" a very constant and fixed degree of stability in form and relations. They admitted that "species" might, and very often did, vary; and that changes in form, size, colour, or general appearance, might, from the operation of external conditions, be produced. And they further allowed that the changes so produced in certain individuals of the species might even be transmitted to the progeny of such individuals, and that these alterations might in this way become more or less of a permanent nature. Such individuals, or their progeny, in which "variations" became thus perpetuated, were known as "Varieties." These "varieties," however, in most cases,

showed a disposition to return to the likeness of the "species;" but when a "variety" became to all appearance permanent, it constituted a "race." "Races," in other words, are permanent or perpetuated "varieties."

Now, it is chiefly from the admission of this greater or less degree of possible "variation" in species that the modern significance of the term has assumed so wide a difference from that in which it was formerly held. And it is around this point that the heat and fury of the battle of the theories appear to rage. Hence the issue at large appears to assume the form of the question 'whether or not "species" is variable without the limits which former opinions set; and, if so, what are the causes or conditions which determine the variations, and to what degree may such variations extend?' Is Forbes's dictum, that "every true species presents in its individuals certain features, specific characters which distinguish it from every other species, as if the Creator had set an exclusive mark or seal on each type," consistent with facts as they now stand? And can we maintain, in the face of recent investigations, the community of descent and primitive origin of species commonly insisted upon in the older definitions? Such are the questions which the biologist has inevitably to meet and answer, and such is the bent of the observations to which we must next direct attention.

Taking origin from the admission that the individuals of a "species" exhibit among themselves variations in form and structure, we find that modern theories assign to such variations not only a far wider range than was formerly accorded, but the variations are also held to possess very intimate relations with the "origin" and ultimate development of the particular "species" in which they are perceived, and with that of neighbouring or distantly connected species also. This statement leads us, then, to notice the first part of the question which we enunciated above—namely, "whether species is variable without the limits which former opinions set."

Naturalists, as we have observed, have long admitted the existence of variations in "species;" and it is these variations, and the estimation in which they are held, that have caused so much dissension as to the universal recognition of many animal and plant forms as true and undoubted "species," on the one hand, or as mere "varieties" of a "species," on the other. And in certain species, the existence of so-called "dimorphic" or "trimorphic" forms—that is, forms included in a single "species," but exhibiting differences among themselves of insufficient value to constitute "varieties"—has but rendered the task of accurately limiting or defining such "species" all the more hopeless and confusing. Then, even among the individuals composing most normal and perfectly ascertained "species," there is no immunity from variation to a greater or less degree, but, on the contrary, a marked tendency towards alteration and variability.

If the existence of this variation in "species" be admitted—and we apprehend that it will now be universally allowed—it remains yet to be shown whether or not this variation exceeds the ordinary limits which are commonly assigned to it. We have seen that the variation first becomes definable to form the "variety," and that the variety becomes perpetuated to form the "race." Now, if we admit that the "race" is subject to the same variations to which the species is liable, then the "race" in turn becomes an unstable and mutable quantity. The influences affecting the individuals of the "species" may equally well affect the individuals of the "race." The conditions which vary the "species" may, in the order of a logical sequence, be supposed, and are, capable of effecting "variation" in the "race" also; and if we conceive that variation may thus be illimitable, we are prepared to admit that the divergence may proceed almost *ad infinitum*.

Such are the effects which are now well ascertained, through the researches of Mr. Darwin and others, to be produced among the constituent individuals of a "species" by the external and modifying influences of climate, food,

domestication, and by other causes allied in nature to these latter; or even, in many cases, without the operation of any apparent or defined cause.

The question of the variation of "species" beyond the limits which former opinions set, may, I think, be thus settled by the confirmation that these limits are exceeded to an extent for which the older theories and definitions would be quite unprepared. The question so far has been a morphological one. We have, in other words, been considering "species" relatively to variations in form, appearance, and structure.

Physiology appears in the next stage to answer the question as to "community of descent," and as to the degree to which such variations may extend. The supposition that "species" may have sprung from a single pair, or from pairs of similar individuals, we have observed to underlie, in a greater or less degree, all the definitions of "species" which have been given. And accordingly we find this idea of a common and similar descent to be embodied in the generally accepted notions—namely, that the power of propagating and producing a progeny which shall be equally capable with the parents of perfectly reproducing their like, is confined to the individuals of each "species" or of each "race," as the case may be. In other words, the so-called "physiological species" is constituted by "groups of individuals which breed freely together, tending to reproduce their like." The offspring of the true physiological species, therefore, normally tend to resemble their parents, and in turn to reproduce their like.

And such an admission or statement is merely tantamount to asserting that individuals belonging to different "species" do not generally breed together; but that, if they do breed together, the progeny, known as "crosses" or "hybrids," will be sterile, or incapable of reproducing their like. But "hybrids" are not universally sterile. On the contrary, very many instances might be adduced to show that whilst "hybrids" have been perfectly fertile, the progeny of

admitted and true "varieties" of a species may be sterile. And, in the face of these and allied facts, the rigidity and unexceptionable nature of the "physiological species" would appear to share no better fate than that which befalls the morphological aspect of the term. The test of "infertile hybridism," therefore, as distinctive of the "physiological species," is not of universal application. Whilst we admit its general truth, we must protest against its universal correctness. And when we add to the foregoing considerations, that in many cases the hybrid "races" so produced seem to be more or less perpetuated, and to continue to produce among themselves fertile progeny, we shall have said enough to convince the reader that "species," in the light of a "physiological" quantity, must present to our modern ideas a very different aspect from that in which it was regarded of old.

The following conclusions, therefore, seem fairly deducible from our considerations :—

Firstly : That "species" is of two kinds, or may be regarded as involving two distinct yet connected aspects —"morphological species," meaning the most limited group of individuals distinguished by the possession of a common character, and separated from all other groups by such a character ; and "physiological species," denoting those groups of individuals "which breed freely together, tending to reproduce their like."

Secondly : That neither "morphological" nor "physiological species" are constant quantities, but are, on the contrary, subject to greater or less degrees of variation and change.

Thirdly : That the test of "infertile hybridism" is rendered invalid in many cases by the recognition of the facts, that whilst certain individuals may be even more fertile with individuals of another species than with those of their own, and whilst true "varieties" of a "species" may be sterile when interbred ; so, on the opposite side, the individuals of separate and entirely distinct "species," and the hybrid progeny resulting therefrom, may be perfectly fertile when "crossed."

Fourthly: The fertility or sterility of "hybrids" is subject to so great variation, that no great dependence can be placed upon deductions drawn from this latter source. The power of reproducing their like among "hybrids" appears to be affected by conditions and causes different, in degree at any rate, from those which affect the "species" as a whole. And

Fifthly: So far as research has proved, the fertility of "hybrids" tends to become lessened in time—this fact to be taken consistently with the progress of experimental study and research.

The term "species" therefore possesses, in these days, a significance widely altered from that in which it was formerly held. It no longer expresses an immutable or fixed quantity, neither does it possess an absolute meaning; and recognising the shifting nature of the question as it now stands, we may, most consistently with the demands of scientific accuracy, regard "species" in the light of an abstract term, of service to us in embodying an idea and starting-point in our system of classification. The term may therefore be now taken to mean 'a group of individuals possessing a general likeness or resemblance to one another, which, in the usual order of circumstances, produce new individuals; these latter exhibiting among themselves the same general resemblance, but liable in themselves, and in the case of their progeny, to greater or less variation from the distinctive characters of the species.' We thus entirely, for the present, shun the question of "community of descent," from its more theoretical and less tangible aspects at least. This consideration will more appropriately occupy us when treating of the theories regarding the origin of living forms in general. And it is also needful, by way of conclusion, to remark, that the "variation" mentioned in the latter part of the above definition of species is to be regarded, like the term "species" itself, as somewhat of an abstract term, embodying the recognition of certain phenomena, but at the same time admitting the necessary imperfections of the data on which the existence of such phenomena or con-

ditions is founded—imperfections these, which time and research will undoubtedly go far to remedy and improve.

Accepting, then, this provisional idea of "species," we have no difficulty in readily recognising the existence of many and familiar "species" of living forms in the world around us. We familiarly talk of the various "species" of animals or plants; employing the term popularly, as already remarked, in the sense of the word "kind." In this abstract sense, therefore, any one animal and its progeny may constitute the type of a "species;" and into such a group, all forms related to it by that nearness of relationship expressed by the term "kind" will be placed. For example, the "domestic" mouse and all its "kind"—that is, all other "domestic" mice—constitute, in this light, a distinct "species" of mice. The essential of which statement lies in the patent fact, that all "domestic" mice exhibit certain characters, generally of constant nature, and by these characters they are distinguished from all other animals, and primarily from all other mice. Thus we find certain characters in form and habits, by which we distinguish the "domestic" mouse from other "kinds" of mice, such as the "harvest" mouse and "field" mouse. And we have in these latter forms, examples of two other "kinds" or "species" of mice, and further research would, in all probability, bring as many more "species" to light. So with the differences between horses and asses, or between many other forms, which a cursory glance throughout animal or plant worlds will detect and exemplify.

A step upwards in the taxonomical ladder brings us to the "genus," which is defined as a group embracing a number of "species," closely allied to each other in all essentially structural peculiarities, but which may be subject to minor differences in form, colour, size, and general appearance. There is, therefore, a closer resemblance and relationship between "genus" and "species," than between any of the other groups, in the scale of classification. The Rats thus form a group of sufficient nearness and resemblance to the Mice, to be included in

unites the classes *Mammalia, Aves, Reptilia, Amphibia,* and *Pisces,* to form the *Vertebrate* type, or "sub-kingdom," as it is termed in the scheme of classification.

Such is a brief exposition of the system of classification of the animal series; a scheme admirably suited to the purposes of the systematic naturalist, and which presents the included forms in a sufficiently clear and ready manner, for the due investigation of the relations between individuals, or groups of individuals. The advance of scientific research will, doubtless, detect its more special and particular imperfections, and at the same time tend to their amelioration; but its general plan, founded on the deductions of morphology and physiology, presents us with as near an approach to a truly philosophical scheme as can well be expected or desired.

Lastly, the still existent and popular idea of a linear or continuous arrangement of the animal or plant series may be briefly noticed in the present instance. Such an idea may be regarded as a lingering remnant of that primitive classification already pointed out; which, destitute of a sound basis of morphological and physiological knowledge, sought to arrange animal forms in a single, continuous, and unbroken series. And it was thus conceived possible that we could pass continuously, and through a graduated series of animals, from the lowest to the highest form; each step or form in the series being supposed to be higher and lower than its respective predecessor and successor.

We have already seen, however, that the rank of every animal form is determined, firstly, by its special fundamental structure or "morphological type," and secondly, by the relative degree of perfection to which the "special isation of functions" is carried out in its economy.

There can, therefore, be no comparison drawn betwe any two animals belonging to different morpholog types, on the ground of the greater physiological per tion of either; nor, *vice versa,* can we compare two mals physiologically the same, but belonging to dif types of structure. A *Cœlenterate* animal, in virt

its "type," is thus a higher animal than any *Protozoön;* and, similarly, an *Echinozoal* animal is of a higher type of structure than a *Cœlenterate.* Every *Annulose* form is *morphologically* inferior to a *Mollusc;* but the higher *Annulosa*—such as the insects, spiders, and crustaceans —are *physiologically* higher than the lower *Mollusca,* represented by "sea-mats" and "sea-squirts." But if, following the dictates of a "linear system" of classification, we were to arrange and classify the *Mollusca* and *Annulosa,* we should have to place the "sea-mats," and other lower Molluscs, below the insects, spiders, and crustaceans—a procedure obviously inconsistent with the nature of either series of organisms, when we reflect that the "type" upon which the "sea-mats" and all other Molluscs are constructed, is a higher "type" than that upon which the *Annulose* body is built up.

Thus the higher members of each type are *physiologically higher,* and at the same time *morphologically lower,* than the lower members of the superior and succeeding sub-kingdom. And whilst morphology thus refuses its assent to the construction of a "linear classification" on the ground of distinctive types, physiology also discountenances the idea on the ground that two organisms belonging to different types of structure may possess an equal physiological status, which would render it impossible to classify one above the other in so far at least as the functional perfection of either was concerned. Both morphology and physiology, therefore, discountenance the idea and scheme of a "linear series" of organic forms, as utterly incompatible with the natural arrangement, disposition, and relations of living beings. Morphology and [illegible]siology, together, express the correct status of any [illegible]en form; but mere physiological differences are of no "[illegible]ment in the face of the considerations relating to th[illegible] and to the fundamental plan of structure: that wh[illegible] animal form must primarily be considered in re- obse[illegible] to its type. It can only be compared, so far, at and [illegible]te, as classification is concerned, with the mem- [illegible] the [illegible] type, and not with those of any higher [illegible] type.

CHAPTER VIII.

The Origin of Animal Forms—Difficulty of investigating the Subject—Theoretical Nature of the Subject—Theories of "Origin of Species"—Doctrine of "Special Creation"—Hypotheses of "Evolution"—Lamarck's Theory of "Progressive Development"—Mr. Darwin's Theory of "Natural Selection"—Examination of the Darwinian Hypothesis—Criticisms of and Objections to the Theory—Objections to the Theory of "Sexual Selection"—Tendency of Evolutionary Doctrines.

HAVING acquired some idea of the nature of "Species," and bearing in mind the considerations which, in the preceding Chapter, were brought before us, the present may be deemed the most fitting stage for a brief review of the more important doctrines which in our day occupy the scientific mind, and which profess to elucidate the primary origin and successive development of the living forms which people our globe. Naturally enough, the human mind and imagination has not in any age rested content with the mere admission that living forms exist, and pass, in the course of that existence, through a series of changes more or less defined. On the contrary, the mere observation of these changes has led to the investigation of the relations of forms in the past, and with one another; and, in a perfectly natural sequence, has followed the endeavour to trace through its complicated series the progress of creation and development, and ultimately to arrive at a conception of the "beginning" itself.

The pursuit of a task, which from its nature is susceptible of little or no aid from the consideration of an unknown "past," has necessitated the very close observation of an ascertainable "present." And it is from the particular construction which may be put upon the p[illegible]able the

respective theories of the origin of life and living beings derive their characteristic tenets and tendencies. We have already seen that the "species" forms the unit quantity of the organic series, and may therefore be held to represent in itself the entity peculiar to the whole series. Hence the theories which deal with the origin and relations of living beings, have directed their attention to the relations which exist between living "species" of animals and plants; since it is from modifications and variations in the development of individuals, that we may naturally argue respecting the relations of the larger groups which the collection and grouping together of individuals tend to form.

It may be well at this stage to remind the reader that we now enter upon the domain of theory and hypothesis; an assertion tantamount to the advice to be discriminating and cautious in our interpretation of the facts or experiments upon which the respective theories are based, and by which they are supported. Nor do I think that to remind the student of science, in all its aspects, that the search after truth is to be his only and constant aim, is a duty at all lying without my present province as a teacher of the principles of biology. The sacrifice of ascertained facts and convictions to preconceived notions and ideas, is a crime in an avowed truth-seeker, which, unfortunately for the advance of truth of all kinds, is but too common in these days; and one cannot escape the thought that the special odium attaching itself to any particular side or party, is the cause of more hindrance to the advance of scientific thought than can well be conceived. Nor must it be lost sight of that the conclusions to which the earnest thinker may be led, may be, and very often are, at variance with the preconceived ideas of even religion itself. And hence arise those much-to-be-deplored conflicts, from which neither party can be said to benefit, which frequently sow the germs of bitter enmity between minds that might and ought to be above the ordinary run of human passions, and which further tend to foster the very spirit of antagonism between science and

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religion, which it is professedly the aim of both parties to avoid and extinguish. It is, in short, the old story of the fight between "orthodoxy" and "heterodoxy;" though we may account it a significant fact that the relative ideas involved in the use of these latter terms are susceptible of being very differently construed from the sense in which they are commonly used. Let plain truth and accuracy become the watchwords of a true system of "orthodoxy," and we shall then be able to discern who are the obstructives in the way of progress, scientific and social. These few considerations will not, I trust, be deemed unnecessary in entering upon the study of a field of thought, which, more than any other, has been, and still is, the scene of much unseemly strife and argument.

Two leading views or ideas would appear to have existed regarding the primitive origin of living forms, or "origin of species," as the subject-matter of the theories is now more commonly denominated. The first of these views is known as the "Doctrine of Special Creation;" whilst the second, termed the "Doctrine of Evolution," comprehends, under this single term, a number of more or less closely-allied theories.

The first-mentioned theory, depending upon and taking origin from the recognition of what has been termed "the Hebrew cosmogony," presents us with a very plain and easily-understood explanation of the "origin of species." This first hypothesis maintains that each species originally sprang from one or more parent-stocks, these "parent-species" being "specially created"—that is, produced by the operation of a supernatural creative power. The theory also is based upon the recognition of the immutable or unvarying nature of "species," and upon the supposition that each "species" was created within a certain area, termed its "specific centre;" and that from this "centre" the "species" subsequently radiated and dispersed itself in an area more or less wide, and according as external conditions were favourable or prejudicial to its extension.

As thus expressed, we have to bear in mind the follow-

ing points regarding this almost self-explanatory theory. Firstly, the operation of a creative power; producing, secondly, the different distinct and generally immutable "species;" thirdly, the distribution of these species from "specific centres;" and, fourthly, the accounting for geographical separation of "species" by changes of geological or physical nature, operating subsequently to the creation of the species in their respective "specific centres."

The "theories of evolution" or "transmutation," as implied by the meaning of the term, maintain that the existing "species" of animals and plants have in all probability been *evolved* from, or are modifications of, pre-existing "species;" or, to use the introductory words of Mr. Darwin himself, "that species undergo modification, and that the existing forms of life are the descendants by true generation of pre-existing forms." And carrying the process of analogy and argument still further, the evolutionist may hold that all the varied and existing forms of life may, by a similar process of evolution from pre-existing forms, have arisen or been produced from one, or from a few primæval forms. In other words, that existing species of animals and plants may have had common progenitors, in a few primitive and original forms of the simplest organisation.

The following passage, culled from Mr. Darwin's "Descent of Man," will give a preliminary idea of the supposed nature of the mode of origin and derivation of the highest form from pre-existing and lower forms:—"Man," according to Mr. Darwin, "is descended from a hairy quadruped, furnished with a tail and pointed ears, probably arboreal in its habits, and an inhabitant of the Old World. This creature, if its whole structure had been examined by a naturalist, would have been classed amongst the Quadrumana, as surely as would the common and still more ancient progenitor of the Old and New World monkeys. The Quadrumana and all the higher mammals are probably derived from an ancient marsupial animal, and this through a long line of diversified forms, either

from some reptile-like or some amphibian-like creature, and this again from some fish-like animal. In the dim obscurity of the past we can see that the early progenitor of all the Vertebrata must have been an aquatic animal, provided with branchiæ, with the two sexes united in the same individual, and with the most important organs of the body (such as the brain and heart) imperfectly developed. This animal seems to have been more like the larvæ of our existing marine Ascidians than any other known form."

We find, however, that the "theory of evolution" is by no means so recent as we might be led to think. On the contrary, it possesses a very considerable antiquity; and although, in the present day, we find that theory and fact approach more closely than before, yet the groundwork of the hypothesis was laid many years ago. Lamarck was probably the first who advocated the theory on truly philosophical grounds. This naturalist, in the beginning of the present century, announced his conviction that living forms or "species" were merely modifications of, or were descended from, pre-existing "species." And Lamarck further believed that the perpetuation of new forms so produced, was secured by the agency of physical or external conditions, by the effects of interbreeding, and by the results of the use or disuse of organs or parts. Such were the chief ideas involved in Lamarck's "Theory of Progressive Development." And although, since the days of Lamarck, evolutionists have seen reason to discard his more particular and peculiar views, yet the principle he asserts remains essentially the same—the theorists of to-day differing from him only in the recognition and maintenance of different means or agencies by which the primary process of the modification of "species" is brought about.

The "Darwinian hypothesis" forms the chief bulwark of Evolutionism in the present day. The theory promulgated by Mr. Darwin has acquired a fame far exceeding that which has attached to any previous hypothesis, and there are few educated persons who do not possess some

knowledge of the main ideas and principles involved in this theory.

In this hypothesis Mr. Darwin accounts for the modification of species, by primarily supposing the existence of certain primitive and common stocks or progenitors, and the development from these common stocks of "varieties." These "varieties" by perpetuation become first converted into "races," and from "races" into new and distinct "species." The agency by which this process of evolution—first of "varieties," then of "races," and finally of "species"—is accomplished, is that of "Natural Selection;" a process exemplified in the "artificial selection" exercised by man in mating together individuals of a species which possess any special variation from the "specific" type. In this way, man, by the "artificial selection" of particular individuals, perpetuates "varieties" to form "races;" and similarly, by "natural selection," nature may be supposed to select individuals which possess any peculiarities or variations, and thus cause these variations to be perpetuated, to form, firstly, "varieties," then "races," and finally distinct "species." The expression, "struggle for existence," has been brought into use to imply the conditions under which "natural selection" operates; those conditions consisting in the competition for food, and for the other necessaries of existence. And hence this struggle for existence results in the "survival of the fittest;" the "fittest" forms being those in which peculiarities of form or habits exist, and which, therefore, transmit to their progeny those variations, from the perpetuation of which, "varieties," "races," and "species," are respectively evolved.

Latterly, Mr. Darwin has introduced into his theory another modifying influence, namely, that of "Sexual selection." The instincts of sex and of the sexual relations of forms, are by this second theory believed to exercise a powerful influence over the production of variations in form.

The primary points from which Mr. Darwin proceeds

to draw his conclusions, and upon which his hypothesis is based, are those, firstly, of the recognition of variations among the individuals of a "species," and of such variations being capable of transmission, so as to become perpetuated in "races."

We have already observed that there is an admitted tendency to variation and modification of the "specific type" among the individuals of most "species;" the general resemblance of the progeny to the parent exhibiting variation to such a degree, that in some cases the divergence amounts to a positive unlikeness. Such divergence generally tends to become perpetuated, although the limits of divergence, equally with the extent of perpetuation and with the causes of variation, are as yet comparatively undetermined. Concerning these points Mr. Darwin says—"The effects (of variations) on the offspring are either definite or indefinite. They may be considered as definite when all or nearly all the offspring of individuals exposed to certain conditions during several generations are modified in the same manner. It is extremely difficult to come to any conclusion in regard to the extent of the changes which have been thus definitely induced. There can, however, be little doubt about many slight changes,—such as size from the amount of food, colour from the nature of the food, thickness of the skin and hair from climate, etc. Each of the endless variations which we see in the plumage of our fowls must have had some efficient cause; and if the same cause were to act uniformly, during a long series of generations, on many individuals, all probably would be modified in the same manner. . . . . . Indefinite variability is a much more common result c of changed conditions than definite variability, and has pro bably played a more important part in the formation nd our domestic races. We see indefinite variability in the endless slight peculiarities which distinguish the i is viduals of the same species, and which cannot be acc for by inheritance from either parent or from some ilwark remote ancestor." romul-

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mission are at once numerous and well-ascertained, and we need not therefore take up space by repeating and proving here what every biologist, whether inclining to evolutionism or not, will readily admit. Mr. Darwin believes that a normal process of "true generation" or "inheritance" will, in ordinary cases, suffice for the transmission of variations to progeny.

The next point to which attention may be called, is the possibility of producing a "breed" in which the variations and peculiarities just alluded to will in turn be *perpetuated*. Examples in proof of this possibility are found in the process of "artificial selection," by means of which breeders of stock have succeeded in rendering permanent the variations or peculiarities found in different individuals of a species, and from "varieties" so constituted, new and distinct "races" have eventually been formed. And a chief point in the argument is held to be the fact that such artificially-selected "races" are distinguished by characters as distinct as those which distinguish and separate true "species."

Next in the chain of evidence come the links relating to the variability in turn of the "races." As "varieties" have been produced from "species," and perpetuated "races" from the mere "varieties," so it is assumed variations will arise among the races so produced. A lengthened period of time is demanded, no doubt, for the evolution of the new "species" from the "races;" and this demand for time has formed, as we shall have occasion to observe, one of the chief objections to Mr. Darwin's theory. But, even in the face of this objection, we may not only find, it is alleged, new "races" evolved from existing and previously modified "races," but these new "races" may evince differences in structure so remarkable and obvious as to resemble those which exist between ordinary and recognised "genera" and "species." Thus, from the single species of the Rock-Pigeon (*Columba livia*), have descended numerous breeds, these latter differing from each other in important points connected with size, form, habits, and colour; with the arrangement and num-

ber of feathers; with the development of the "uropygium" or oil-gland; and with the number of vertebræ or segments in the spine. Now, these characters are exactly those by which any ornithologist would distinguish between true "species." In other words, the characters which separate these derived breeds or "races," are similar to those which would, in ordinary instances, be distinctive of "species."

A curious and significant fact in regard to these derived "races," and one worthy of remembrance is, that occasionally we find in tame and "derived" pigeons, and in other forms, some characteristic and special markings peculiar to the Rock-Pigeon or original progenitor from which the various "races" have, as already remarked, been satisfactorily proved to spring. This perpetuation of "race-likeness," or "atavism," as it is called, is to be accounted one of the proofs of the transmission, even through many degrees of kinship, of the characters peculiar to the original and derivative "stock."

The arguments formerly so confidently believed in, with regard to the sterility of "hybrids," have previously been shown to be founded on insecure grounds, although admittedly this subject is one which requires further research. We have already seen that the fertility of such crossed and intermingled forms is, in all probability, destroyed through time.

Bearing in mind the foregoing and preliminary points in the theory, we now proceed to consider the more intimate aspects of "Natural Selection."

The next link is constituted by the statement, for the admission of which we are quite prepared—namely, that the high rate of increase of animals and plants inevitably tends to the production of more individuals than can possibly be provided for. "Hence," says Mr. Darwin, "as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine

of Malthus, applied with manifold force to the whole animal and vegetable kingdoms ; for, in this case, there can be no artificial increase of food, and no prudential restraint from marriage. Although some species may be now increasing, more or less rapidly, in numbers, all cannot do so, for the world would not hold them."

This progressive geometrical increase, then, is held to be a primary condition, influencing the existence and operation of the principle of "Natural Selection." The "struggle for existence" is thus recognised, and in the "struggle" those individuals of a "species" which possess any peculiarity or variation, will tend to be preserved in virtue of the process of "natural selection," over those individuals which do not possess such peculiarities, and which latter, therefore, fall in the "struggle ;" whilst the former, with their variability, are preserved, and perpetuate their peculiarities in their offspring.

Then, finally, this perpetuative process in time intensifies the peculiarities which the "favoured individuals" exhibit, and so the "varieties" become "favoured races," and the races tend to merge into distinct "species," sufficient or "infinite" time being allowed to the perpetuative progress. The difference between a stable "variety" and an ordinary "species" is thus to be considered as a difference only of degree, and one which, from being plainly perceptible, insensibly and eventually disappears.

Such, briefly stated, are the leading ideas in the theory of development by "natural selection." The data upon which the theory of "sexual selection" has more recently become supplementary, and in some degree subsidiary, to the former theory, are chiefly founded on the fact that peculiarities and variations in structure may be transmitted and perpetuated through the "sexual struggles" in which animals are well known to engage, and in which the males, which possess certain peculiarities, will tend to become progenitors before those destitute of such peculiarities or variations. Thus, those males which are the stronger and the better endowed with physical powers, may, in many instances gain pos-

session of the females; whilst, in other cases, the females appear to literally "select" the males, being drawn towards the latter by their brilliancy of plumage, beauty of contour, peculiarity of odour, or excellence in voice. These distinctive points are in fact so many peculiarities, which will be naturally transmitted to the progeny, and so become intensified in the progress of perpetuation.

These ideas may serve to guide the reader in his personal examination and perusal of Mr. Darwin's works; for to remain ignorant of the facts and theories therein expressed, would be to ignore the most fertile source of advance and progress in biological thought, which the present century, great as it is in power of research, has seen. However authorities high in worth and position may differ from the theory, and however deficient or erroneous many points may hereafter be proved to be, we must acknowledge that, by its aid, not only have many valuable biological principles been constructed or strengthened, but we also receive, through the facts and research incidental to the theory, many explanations of biological phenomena which formerly were either neglected or considered wholly inexplicable. Indeed, the influence of researches and thoughts such as those of Mr. Darwin, has stimulated and invigorated workers in all departments of natural science; and, although we may differ from the ulterior views which the theory and its facts tend to support, we must still own and admire the earnest work and laborious research which have contributed so largely to our stores of knowledge. We would certainly prefer to support a scheme advocating the recognition of certain and defined laws, even though these necessitate the destruction of seemingly sound views, than to adhere to the opposite and other extreme of maintaining a system without regulation, or, at any rate, one, the regulation of which we must profess ourselves incompetent to explain.

As might be expected, the Darwinian theory has been subjected to many searching criticisms, with the general result of modifying several important features and

particulars. The chief arguments against the hypothesis of "natural selection" are founded on, or drawn from, the consideration of the following points :—

Firstly, that the theory of "Natural Selection," *per se*, is incompetent to account for the beginning or initiatory stages of the variations, upon the presence and ulterior transmission of which, the theory, as we have shown, principally depends. That these variations are subject to and regulated by certain determinable laws there can be no doubt, but of these laws Mr. Darwin's theory can give us no account. The mere *beginnings* of those stages of variation, which appear in course of their full development to be so fully accounted for, are thus left unexplained and undetermined.

Then, secondly, just as we perceive in individuals variations which are capable of transmission and of being perpetuated, so it may equally well be maintained that other kinds of variations and peculiarities exist, which latter, so far from tending to preserve and perpetuate the "species," would, on the contrary, conduce to its extermination. The existence of these unfavourable variations, and their effects, the theory of "Natural Selection" appears inadequate to explain.

Thirdly, the difficulty of proving that variations may occur in more than one individual of a "species" at one time, is supposed to found another objection to the favourable recognition of the theory. "Natural Selection," it is held, must require for the due perpetuation of variations, the existence, in a *number of individuals*, of the peculiarities to be transmitted. It is accordingly denied that specific peculiarities occur, either in such a number of individuals, or are so frequently exhibited, as to warrant the belief that the process of "selection" alone is competent to effect so great and ulterior changes in the form and constitution of the "species."

Fourthly, "Natural Selection" appears to take no cognisance of the facts that the progeny of many "species" includes normally sterile individuals, incapable of reproducing their like. Examples of such sexless forms are

seen in the so-called "neuters" of many insects, such as the Bees and Ants. The evolutionist would, probably, account for such peculiarities by supposing the existence of some primary cause or condition affecting the development in these forms of the reproductive organs; but, at the same time, this mere statement is quite inadequate to explain the production of such individuals from parents whose reproductive organs are fully and perfectly developed. The consideration of the ordinary law of inheritance, in virtue of which alone the process of "Natural Selection" is conceivable of operating, offers, in a case like the present, a grave objection to the theory.

Fifthly, naturalists are by no means agreed as to the limits by which the variability of "species" is confined. We have already seen that "Natural Selection" chiefly relies upon the "indefinite variability" of forms—that is, it maintains that there is no absolute limit to the extent of possible variation. Mr. Mivart, in his "Genesis of Species"—one of the most philosophic of the many works which oppose the Darwinian theory—states this objection thus:—"The opinion that species have definite though very different limits to their variability is still tenable." Every one must admit that every species is "variable" to a greater or less degree; but considerable difference exists as to the probable boundaries of such variability. Our utter ignorance of the laws which govern these variations is, as has been elsewhere pointed out, a chief reason for pronouncing a very guarded opinion on this head. But from a careful consideration of the facts which have already been brought to light, there appear grounds for the belief that a limit does exist to these variations; and the instances, in cases of variation, of "atavism," or "reversion" to the characters of the original "stock," seem to show the tendency of variability to become limited or diminished, and to give place to the original characters of the "species." Mr. Mivart cites as examples of this "atavism" or "reversion," the fact that "the feral rabbits of Porto Santo, Jamaica, and the Falkland Islands, have not yet so reverted in those several

localities. Nevertheless, a Porto Santo rabbit brought to England reverted in a manner the most striking, recovering the proper colour of its fur 'in rather less than four years?' (Darwin). Again, the white silk fowl, in our climate, 'reverts to the ordinary colour of the common fowl in its skin and bones, due care having been taken to prevent any cross' (Darwin). This reversion taking place in spite of careful selection is very remarkable. * * * These facts seem certainly to tell in favour of limited variability, while the cases of non-reversion do not contradict it, as it is not contended that all species have the same tendency to revert, but rather that their capacities in this respect, as well as for change, are different in different kinds, so that often reversion may only show itself at the end of very long periods indeed."

Sixthly, "Natural Selection" appears incompetent to explain the many instances of sudden development of "specific differences." We have seen that, in the view of Mr. Darwin's hypothesis, "Natural Selection" acts essentially and only through long periods of time, and tends to produce differences in species in a very gradual manner. In opposition to this opinion it is attempted to be shown that "specific differences" frequently become apparent at once, and suddenly; and in this view there must be some other and equally important and powerful cause than the slowly-operating one of "Natural Selection."

Mr. Mivart notices, in support of this objection to Mr. Darwin's theory, the sudden development in oysters removed from "the shores of England and placed in the Mediterranean," of a "mode of growth," and of "prominent diverging rays, *like those of the proper Mediterranean oyster*." In this, and in many similar instances, therefore, "Natural Selection" appears incompetent to explain phenomena, which in themselves exhibit results, attainable, in virtue of Mr. Darwin's theory, only through a long course of years, and through innumerable stages of perpetuated variation.

In the seventh place, the absence of what are known

as "transitional forms" between species, affords an argument of considerable power against the evolutionist theories. "Certain fossil transitional forms are absent, which might have been expected to be present." The question before us is, therefore, one of *time*—the existence in time past of "intermediate forms," and the probability of the duration of past time, as insufficient for the purposes of the evolutionist.

Firstly, then, if existent species have descended from pre-existing forms by a process of modification of these latter, we might reasonably and naturally expect to find in the past or geological history of our earth, traces of intermediate organisms, which would connect existing forms with those species from which they were evolved. And these "transitional" forms would thus unite in themselves the structural peculiarities of the pre-existing and of the derived species. Does the study of fossil organisms, of palæontology, and of geological life and time, therefore reveal any such forms? Can the palæontologist, in other words, point to fossil organisms, which can be said to evince a transitional nature of this kind, or to form connecting or intermediate links in the graduated scale of structure, which the evolutionist necessarily proposes and requires? These queries must be answered in the negative, since the study of palæontology has not brought to light any organisms which cannot be referred to existing types of structure, and which therefore can be said to present in themselves the united characters of any two known species. But if the evolutionist theory be true, we should expect to find very many examples of such forms. The continuous and graduated structural chain which the evolutionist demands has, therefore, no existence in nature. The geological record reveals only forms separated from each other by boundaries and characters as sharply defined as those which mark the differences between existent species. The missing links which palæontology should supply are thus wanting; and even in the new and most recent life-periods, which include the fossil remains of those forms

at present existent, and of those species most nearly allied to them, we cannot detect any evidence of transitional forms connecting intermediately the forms of the present with those of the past.

It is, however, to be noted that very high authorities have attempted to demonstrate the existence of organisms which unite the characters of distinct "species" of animal forms; and which, therefore, may be supposed to exhibit that gradation of form consistent with the theory of the evolution of existing forms from pre-existing "species." Thus the extinct *Dinosaurian* (Reptilian) forms have been asserted to exhibit marks of identity with birds on the one hand, and with reptiles on the other; that, in short, the Dinosauria represent a group of transitional forms, exemplifying the gradual evolution of the bird-form from that of the reptile. As Mr. Mivart remarks, however, "the mass of palæontological evidence is indeed overwhelmingly against minute and gradual modification. It is true that when once an animal has obtained powers of flight its means of diffusion are indefinitely increased, and we might expect to find many relics of an aërial form and few of its antecedent state—with nascent wings just commencing their suspensory power. Yet had such a slow mode of origin, as Darwinians contend for, operated exclusively in all cases, it is absolutely incredible that birds, bats, and pterodactyles, should have left the remains they have, and yet not a single relic be preserved in any one instance of any of these different forms of wing in their incipient and relatively imperfect functional condition!

"Whenever the remains of bats have been found they have presented the exact type of existing forms, and there is as yet no indication of the conditions of an incipient elevation from the ground.

"The pterodactyles, again, though a numerous group, are all true and perfect pterodactyles, though surely *some* of the many incipient forms which, on the Darwinian theory, have existed, must have had a good chance of preservation."

Where forms approaching in nature to the intermediate exist therefore, they are themselves distinctly separated from the groups with which they are related, and the gaps between forms thus seemingly allied, are in this way left yawning as widely as before. The Dinosaur may be conceived, for example, to unite something of the bird with something of the reptile ; but we still require, for the purposes of "Natural Selection"—if not for the purposes of all other forms of the evolutionary theory—the existence of a multitude of forms representing the gradual and successive stages of modification between those rudely transitional organisms. We yet require to bridge over the immense space which intervenes between the Reptile and the Dinosaur, and then between the Dinosaur and the Bird. "Natural Selection" demands a host of graduated and transitional forms, which palæontology fails to furnish ; and the subject is further complicated for the Darwinian theory, if we consider that such transitional forms should, on all accounts, have had as good chance of preservation as the Dinosaur itself. And, as has been remarked, the preservation of the Dinosaur alone, and the absence of any intermediate forms, may be used as an argument in favour of the point already insisted upon — namely, the "sudden," instead of the "selective," and consequently gradual, origin of "species."

The question of time also offers a second aspect unfavourable to the theory of "Natural Selection" in particular and of "Evolution" in general. We have already seen that the evolutionist requires an immense period of time for the necessarily slow and gradual origin of new "species" through and from pre-existing forms. Physicists have accordingly seen reason to dispute the fact of the possibility of time past having been of duration sufficiently long for the purposes of the evolutionist. Time past for him must be practically infinite ; but the physicist holds that his demand is excessive, and inconsistent with the results of physical research.

Sir William Thomson's views are those which are

commonly quoted against this demand for time infinite. These views are founded on certain calculations recently made by the above-mentioned distinguished physicist, with the result of restricting time past to a period of duration overwhelmingly below that required for the modification of species according to the theory of "Natural Selection," and thus practically inadequate in every way for the operation of the "selective" process. No successful attempt at refutation of these views has as yet been made by Mr. Darwin or his supporters, and the argument thus derivable from the question of time is one of the most potent against the evolutionist's views.

Although the evolutionist may, therefore, cut down and limit the time required for specific change, yet by his own showing that change is of slow operation, and of very gradual progress. And he is therefore placed in the dilemma either of shortening the period of time he requires, or of hastening the "selective" process; either of which modifications will tend to powerfully militate against the validity of his theory.

Lastly, the theory of "Natural Selection" is proved to be at variance with certain facts observed in the geographical distribution of living forms. The distribution in space of nearly-allied "species," according to Mr. Darwin's theory, should evince a certain amount of near relation—that is, nearly-allied species should consistently be situated in approximate tracts or portions of this earth's surface. Now, a review of the distributional aspects of living beings shows us that, in many cases, species of closely-related nature are situated in widely-separated portions of the earth's surface, and under circumstances which otherwise militate against the application of this theory. No doubt geological and physical changes of very vast extent may be regarded as sufficient to account for the dispersion of these forms; but this very explanation tells somewhat against the operation of the "selective" process, requiring, as it does, the existence of comparatively undisturbed surroundings for the gradual development of those "minute, indefinite, and fortuitous vari-

ations," on which the progress of "Natural Selection" fundamentally depends.

Regarding the subsidiary theory of "Sexual Selection," which is supposed to supply certain wants or gaps in its companion hypothesis, many objections have in turn been entertained to its favourable reception. The presence of colour, sound, odour, in animal forms, as affording means for the perpetuation of variations by sexual selection, is not always satisfactorily explained on this footing. Thus, among the higher apes the males are adorned with brilliant colours, yet the weaker females appear to possess or exercise no power of "selection." Or amongst savages, as remarked by Mr. Wallace, their singing "is a more or less monotonous howling, and the females seldom sing at all. Savages certainly never choose their wives for fine voices, but for rude health, and strength, and physical beauty." "Sexual selection," he adds, "could not therefore have developed this wonderful power (of singing), which only comes into play among civilised people." The varied hues of many lower forms of life, such as are seen among shell-fish, must exist independently of the operation of "sexual selection." Since impregnation is effected in these cases "by the mere action of currents of water, and the least beautiful individual has fully as good a chance of becoming a parent as has the one which is the most favoured in beauty of form and colour." And so, in many similar instances, the doctrine of "sexual selection" can be shown to be inadequate to the explanation of most of the cases in which the conditions it requires to begin with are present in apparently full perfection.

Whilst thus the theories of the evolutionary origin of species endeavour each to reconcile to its particular ideas the probable causes and conditions which prompted and directed the existing order and relations of living forms, we observe that not one is exempt from objections, more or less grave, to its reception *in toto*. Yet from each we may derive a certain amount of information—from some a greater degree and from others a less degree; and, so far from such labours being discouraged, as is occasionally

inculcated upon us, it is clearly our duty to aid in all efforts which tend to the elucidation of the causes and means whereby this wondrous universe and its varied population have been derived, formed, and arranged. And, as a final thought, we must take into consideration the important fact, that future research will, if honestly pursued, tend either to the clear demonstration of truth, or to the exposure of inconsistency and error.

CHAPTER IX.

"Histology"—Intimate Structure of the Tissues of Living Beings—Cells, Fibres, and Membranes—History and Structure of the Cell—Cell-wall—Cell-contents—Nucleus—Analogy between the Cell and the Entire Organism—Physiology and Functions of Cells—Vital Properties of Cells—Cell-reproduction—Origin of Cells—Theories of Schwann, Goodsir, Huxley, Bennett, and Beale—Relation of Cells to Bioplasm—Idea of a "Molecular Bioplasm" as the ultimate Constituent of Vitality.

THE term *Histology* has been applied to that department of morphological science which has for its aim the investigation of the minute structure and composition of the tissues of which the living organism is composed. The birth and progress of this branch of biological inquiry is essentially one with the invention and progressive improvement of the microscope, since the prosecution of histological research is carried on solely by means of this invaluable instrument. And hence the term "microscopical morphology," might be used synonymously with that of "histology." To the rapid strides and consequent extension of information and ideas which the active study of histology made and produced, we owe the elucidation of many intricate points concerning the more abstruse aspects which the study of life and organisation presents to the investigator. Such a branch of inquiry as that at which, in the present Chapter, we propose to cast a passing glance, therefore tends, more perhaps than any other department of biological science, to bring us face to face with the apparently ultimate bounds of human knowledge; and to the influence of microscopical research into the intimate structures of living beings, may in greater part be ascribed the multiplication of theories respecting

the origin of life, and the many other points which are more or less intimately bound up or connected with such a subject.

The uniform, and, in most cases, structureless, substance to which the terms "matter of life," "life-basis," and "protoplasm," or "bioplasm," have been applied, chiefly owes the discovery of its universal occurrence throughout the organic series, to the patient industry of the practical histologist; and throughout the entire domain of biological science there are but few points connected with the structure of the living organism which have not received either confirmation or contradiction from the labours of the microscopist. And more especially to the subject of development does the science of histology bear an important relation; since by aid of the microscope we have been enabled to trace from its primary evolution, not only the developmental progress of the living form as a whole, but also the successive and gradual formation of its component parts and textures. And we have been further informed as to the manner in which the fully-formed and mature tissues carry on the complex processes of nutrition and growth;—funds and stores of information these, the value of which we may best estimate if we compare the darkness of former ignorance with the brilliant light of modern inquiry and research.

The tissues of living organisms admit of division into three obvious groups, each of which may in order be viewed, though not necessarily, as a successive stage in the formation of its succeeding and companion texture. These primary tissues are respectively known as *Cells*, *Fibres*, and *Membranes*. Of these three structures, the *Cell* (Fig. 19, A) is by far the most important, since not only do we find that it contributes to the formation of the other textures, but in certain cases we may observe its capability of constituting, *per se*, a living organism, and, as such, of carrying on all the functions appertaining to the vital state.

In the earlier and necessarily imperfect states of histo-

logical inquiry, the "cell" was regarded as the ultimate or primary constituent and basis of formation of all the tissues and textures of the body; but more recent research has demonstrated that there is a stage of simplicity of form and structure of even simpler type than that witnessed in the comparatively primitive structure of the "cell." Beyond the cell, as evincing the simplest form of determinable structure, we find a more primitive phase of

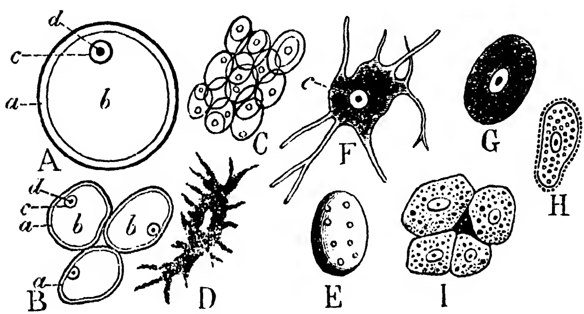

Fig. 19. Morphology of Cells.

A, Diagram of a typical cell: *a*, cell-wall; *b*, cell-contents; *c*, nucleus; *d*, nucleolus. B, A few cells from the "chorda dorsalis" of the Lamprey. C, Fat cells. D, Pigment or colour-cell from skin of frog. E, Vegetable cell, showing "dotting" of cell-wall. F, Multipolar nerve-cell (with many processes) from human spinal cord. G, An oval nerve-cell. H, Cartilage-cell. I, Hepatic or liver-cells—(all magnified).

existence in the structureless "bioplasm" or "life-basis;" whilst beyond this latter material another histological school has insisted on the recognition of certain minute particles of indivisible nature, to which the term "molecules" has been applied, as forming the ultimate constituents from which all the subsequent complexities of form and structure may be and are derived.

The histological battle has therefore been essentially one of contention for the discovery and confirmation of the ultimate and primary constituent of the living form; and in its earlier phases the contest assumed the nature

of one which had for its object the demonstration of the truly vital and essential nature of the "cell." As we shall presently observe, the cell itself, the "cell-wall," "cell-contents," and the cell-centre or "nucleus," have respectively been credited with forming the essential part of the primitive element of form. Whilst the later stages of histological progress have resulted in the recognition and assertion of so-called "germinal centres" and "germinal matter," then of a "physical basis" or "protoplasm," and, lastly, of minute indivisible particles termed "molecules," as the primitive elements of form and structure.

A brief enumeration of these various theories will at once serve to render the reader familiar with the general principles of histology, and to familiarise him with the details of structure deducible from the consideration of that highly important element of form, the "cell."

Most conveniently for our present purpose, we may begin with the investigation of the "cell" and its parts. The most general and typical definition of this structural element is that embraced in the idea of a more or less spherical body, usually of minute size, and consisting (1) of an outer or external envelope, the cell-"wall" (Fig. 19 A, *a*); (2) of an included and more or less solid particle, the "nucleus" (*c*); and, lastly (3), of a substance contained within the cell-wall, and in which the nucleus is generally imbedded, the "cell-contents" (*b*).

These various and separate parts each vary greatly in size, form, and composition; and the cells which result from their combination consequently present wide differences in all these points. However various and diverse the theories which concern the origin, function, or nature of cells, the foregoing essential parts must be recognised as constituting the practical cell of the histologist, or the theoretical cell of the speculative reasoner. Schultze has attempted to show that the "cell-wall" may be dispensed with in our ultimate idea of the cell; and Brücke has similarly insisted that the "nucleus" may, of all the other parts, be most conveniently omitted from consideration.

But the multiplication of such ideas in support of special theories not only tends to render the possibility of arriving at true conclusions exceedingly improbable, but also makes it a very confusing task to distinguish between the relative notions entertained with regard to the typical idea of a cell. And hence, in considering such debateable points as those which constitute the subject of our present inquiry, it is of the utmost importance to start with a clear and unmistaken idea of the conditions common to all the various theories. These conditions we therefore find to consist in the presence, in the typical cell-structure, of a "cell-wall," "cell-contents," and "nucleus."

The "cell-wall" (Fig. 19, *a*), as forming the outer or external envelope and boundary of the cell, offers a convenient starting-point in our examination. This structure we find generally to consist of a structureless, homogeneous membrane, composed, in the animal organism, generally of an albuminoid or protoplasmic substance; and in plants of a material almost identical with starch, and to which the term "cellulose" is applied.

The cell-wall thus generally exhibits a uniformity of structure, although, in many instances, it undergoes a process of hardening or thickening by the deposition or addition of matter, usually to its inner, but sometimes to its outer or external surface. In vegetable cells we occasionally find the cell-wall to be of a double nature, and to consist of, firstly, an outer layer, and, secondly, of an inner and more delicate layer, the "primordial utricle" of Mohl. Lastly, in certain instances the cell-wall does not exist as a distinct and separate structure, but appears throughout its structure to become more or less continuous and identical with the cell-contents, with which, according to certain views to be presently noticed, it possesses relations of the most intimate kind.

Regarding its functions, the cell-wall primarily serves to determine the form and size of the cell, as also to constitute a protecting envelope to its contents. In the exercise of the vital functions of cells, and of the tissues which they tend to form, the cell-wall plays a most im-

portant part. The chief phenomena of interest in which the cell-wall may be said to take part, consist in the transmission through its substance of fluids, which thus may pass from cell to cell with astonishing rapidity. This action is in all probability dependent on the processes named by Dutrochet "endosmose," and exosmose; terms which are used to indicate the phenomena observed in the passage of fluids through membranes differing in structure; the movement of "endosmose" being that whereby a liquid of thin or watery nature passes through a membranous structure, to mix with a liquid of denser constitution. The denser liquid generally at the same time passes outwards, to mix with the thinner fluid, in virtue of the action of the opposite force of "exosmosis." Such endosmotic and exosmotic phenomena are exemplified through the medium of the cell-wall, and thus affect the cell-contents. The remembrance of this phase and function of cell-life will serve to explain many curious and complex phenomena in the nutritive processes of the highest as well as of the lowest organisms.

The "cell-contents" (Fig. 19, *b*) vary exceedingly in nature and composition. In their early state they partake of the nature of bioplastic material; the subsequent changes in the life of the cell, and the development of its characteristic and special features, tending to alter, in a greater or less degree, the composition of this primitive material. The cell-contents may be solid, liquid, or gelatinous; and may exist in the form of crystals, fibres, large granules, or minute molecules.

Within the contents of cells, and particularly in cases where the contents are of a fluid nature, and contain suspended therein particles of a molecular kind, movements of a circular or of a vibratile nature are frequently to be seen. These so-called "molecular" movements—or, after their discoverer, Robert Brown, "Brunonian movements"—are observed to occur in any fluid which contains many particles of a finely-divided nature; but their cause or origin has as yet received no satisfactory explanation. In other instances, a defined circulation of the cell-contents

may be observed; this latter movement usually depending on the presence of vibratile eyelash-like bodies or "cilia," but occasionally being witnessed in the absence of such bodies. To this defined circulatory movement the general term "cyclosis" has been applied, and this primitive circulation is well exemplified in the case of certain of the lower forms of both animal and vegetable life.

The central particle, or "nucleus" (Fig. 19, *c*), forms a structure of very general occurrence in the constitution of the cell, although it is frequently absent or wanting; and may exhibit great variations in form, size, and structure, when present. It may be found imbedded near the centre of the cell-contents, but generally occupies a position near the periphery or outer margin of the cell. It appears also to differ in composition from the cell-wall, and frequently from the cell-contents, inasmuch as the chemical reagents which affect either or both of the latter parts, seem to have little or no effect on the "nucleus."

The "nucleus" is further considered by some authorities to be more of a fatty than of an albuminous nature. It is, however, readily coloured by the addition of carmine and other pigments—a feature exhibited by bioplastic material, and thus of value in the detection of the "life-basis."

Regarding the intimate structure of the "nucleus," it appears to consist, in some instances, of an assemblage of particles or granules; or it may be constituted by a little cell-like membrane, enclosing one or two more solid particles, termed "nucleoli" (*d*). Occasionally more than one "nucleus" may be present in a single cell; but this condition, in all probability, has reference to certain phenomena connected with cell-reproduction, and to be hereafter described.

Regarding the functions of the "nucleus" many and very varied opinions have been entertained. The prevailing idea would seem to regard the "nucleus" as the seat of the reproductive or germinative changes in the life-history of the cell; and this opinion appears to be favoured not only by the actual details and phenomena observed to occur in such phases of cell-existence, but in

the relations of the "nucleus" to the reproductive function in those lower organisms, which, in their life-history, exhibit to all intents and purposes the form and functions of a single "cell." And it has further been observed that "nuclei" in a "free" state, or those which have been liberated from their cells, apparently assume all the functions of true and perfect cells; these independent "nuclei" frequently developing into the form of the cell from which they were derived.

The foregoing observations, on the composition and structure of the cell and its individual parts, will prepare us for entering upon the consideration of the general functions of, and modes of reproduction observed among cells. That the cell, apart from considerations regarding its origin, typifies for us, in the most remarkable manner, the life of the perfect and entire animal or vegetable organism, is the first point worthy our remembrance. The life of each individual cell is strangely analogous to that of the being, in the tissues of which it may be situated. It nourishes itself, and reproduces itself, in the same typical manner, and after the same fashion that the higher animal nourishes itself and reproduces its like; and it thus represents in itself the unity and entity of organic existence. The simplest animal and plant forms present themselves to us in the form of ordinary cells; and, indeed, several forms of undoubted animal organisation do not exhibit anything approaching to the perfection and structure of an organised cell. The *Foraminifera* thus exemplify forms in which the organisation is of a type much lower than that seen in a true and defined cell. And tracing upwards and throughout the created scale the marvellous transformations of cell-life and structure, we find the higher organism to present us with a mere combination of cell-structures; so that, in its most individualised phase, the highest animal or plant may be deemed an independent and single being, only in the sense that the cells of which it is composed co-operate in the most admirable and harmonious manner to the maintenance of the individual existence. Otherwise, they may be

viewed as the semi-independent factors which make up the sum total of the adult existence of animal or plant—as typically, indeed, as the primordial germ-cell represented the whole energies of that early embryo from which the adult form was gradually evolved.

In briefly reviewing the general functions performed by cells and their relations to the organisms of which they form so important a part, the possession of "vital properties" by cells constitutes the first consideration of import to which we may direct attention. In virtue of the bioplastic material from which they are primarily produced, we find an accompanying exhibition of vital power, through the operation of which the cells perform the many complex functions which fall to their lot in the organic economy.

Thus, in the first of the groups, into which we may conveniently divide cells, we find them acting as agents of elaboration, tending to further perfect the character of the fluid in which they are contained. Such are "cells of elaboration," and of this group the cells or corpuscles of lymph, blood, and chyle, present familiar examples. A second set may be named "cells of tissue-formation," in that they tend, by their aggregation and transformation, to form the tissues of the body. Such are the cells which enter into the formation of ordinary cellular tissue, adipose or fat tissue (Fig. 19, C), connective tissue, fibrous tissue, and those other and equally simple membranes, which, apart from the performance of any special functions, fall to be included under the general term of "tissue."

On a third series of cells devolves the performance of secretory and excretory processes, and such may appropriately be denominated "cells of secretion and excretion." These latter are devoted to the secretion of fluids or products of various kinds, which are employed in the varied purposes and functions of the living economy; and they may similarly subserve the function of excretion, and thus excrete or remove from the fluids of the body those waste products which otherwise might injure the welfare of the organism at large. Such cells are exemplified in those of the liver (Fig. 19, I), spleen, kidney, and other glands.

The characteristic "pigment" or "colour cells" (Fig. 19, D), and structures of allied nature, also fall to be included in the list of secreting cells.

A fourth set may be termed "cells of special function." These latter collectively, and in the form of special tissues, subserve many and important functions in the organic economy. Thus the nerve-cells (Fig. 19, F G) of nervous tissue, and the cells of which muscular tissue is composed, are devoted each to the performance of a special function; the former to that of generating and conveying the nerve-force through which the function of correlation is manifested; the latter, of inducing muscular contractility, and, by means of changes in the form of the cells, producing motion and mechanical force.

All these varied and complicated phenomena appear to be induced and originated by the vital "force," or vital properties of the cells—an inherent power peculiar to the cell, in the same degree as it is peculiar to the organism as a whole, and manifesting itself in both, through a series of actions in every way and curiously analogous and similar. In discussing the subject of *Nutrition* we shall have occasion to observe the peculiar vital properties of the cells, as exemplified in the so-called "elective affinity of the tissues;" but the considerations here enforced will serve to familiarise us with the general as well as the more special functions subserved by the cells in all the tissues and structures of the body.

In virtue therefore of the possession by the cells of this vital "force," or of these "properties," we find them availing themselves of the chemical and physical agencies to which they, in common with the entire organism, are subject; these agencies, however, being made subservient to the special functions which the cells are in turn destined to perform. An erroneous view of the properties of cells would attribute to these chemical and physical phenomena, directly, the marvellous powers which we have seen to characterise the history of these and of other living structures. But a due appreciation of these powers, and of their extent, shows us that the influence and action of

purely chemical and physical phenomena are insufficient to produce so wonderful results. These physico-chemical forces are merely the subsidiary agents and conditions, which the presence and directing power of "vital" phenomena call into operation, to aid in carrying on the multifarious duties involved in the action of living and being.

As we have observed cells to play an important part in the nutritive process of the organism, and as by their multiplication to form tissues they may be said to compose the organism as a whole, the function of cell-reproduction assumes a high importance in the consideration of the general economy of the living being. The general term of "cytogenesis" is applied to indicate the phenomena of cell-multiplication and development, and the included reproductive phases have been very accurately determined throughout their entire course. But regarding the primary origin of cell-structures very varied opinions, as we shall presently notice, exist.

Four methods of reproduction may be observed to occur amongst cells. The first and most common of these modes is that of "endogenous division," or "duplicative subdivision," in which process new cells are produced within the first-formed or parent-cells. Such a form of cell-reproduction is very frequently seen among plants, and particularly in the lower or *Cellular* plants (Fig. 20, *a i*); but we also notice the process in the animal world, and typically in the segmentation or division of the impregnated ovum or egg (Fig. 25, A B C D), as will be fully explained in the chapter on *Development*. The essential feature in this first process consists in the subdivision of the "nucleus," or of the cell-contents, into two parts (Fig. 20, *a b c*), and in the formation in this way of two new cells within the old or parent cell. These newly-formed cells may similarly divide, and thus four new cells may be produced; and the process of endogenous multiplication may be further continued, until the rupture of the parent cell liberates the younger structures, and sets them free in turn to propagate and reproduce their like. It is a somewhat significant fact that the impreg-

ated ovum should, in the course of its early develop-
ient, evince the same series of phases that an ordinary
ell exhibits in its endogenous multiplication.

A second method of cell-reproduction is that by
exogenous multiplication." This mode of reproduction
mong cells is by no means so common as the previous

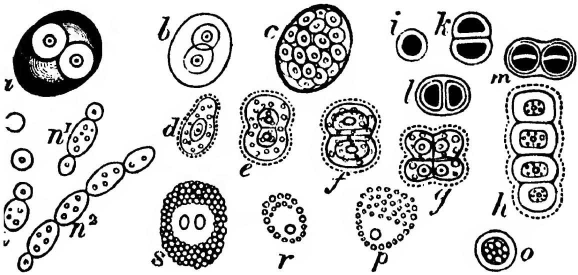

Fig. 20. REPRODUCTION OF CELLS.

Vegetable cell, producing new cells endogenously; *b*, cartilage-cell multiplying by the endogenous method; *c*, more advanced stage of *b*, in which the whole interior of the parent cell is filled with new or embryo-cells; *d*, ordinary cartilage-cell; *e*, the same dividing transversely by a process of fission; *f*, further stage of *e*, showing the complete division of the nucleus; *g*, process of double fission, transversely and vertically, producing four cells; *h*, production of four cells by longitudinal cleavage or fission; *i*, a vegetable organism or *Alga* (*Palmella*), consisting of a simple and single cell (unicellular); *k*, its fissiparous division to form two cells; *l*, more complete separation and distinction of the new cells; *m*, further division of the new cell to form four; *n*, cells of the Yeast Plant (*Torula cerevisiæ*) *n*, single cell; *n*[1], cell producing buds at either extremity; *n*[2], united series of cells, the result of continuous budding; *o*, red snow plant (*Protococcus nivalis*), as a cell reproducing new cells by endogenous multiplication. *p r*, "molecular" formation of cell by aggregation of molecules to form cell-wall and nucleus (Bennett); *s*, molecular cell, with two nuclei (Bennett).

iethod. It appears to be effected by the rupture of a
arent cell, and by the subsequent formation, *without* the
atter, of new cells, by the aggregation of the extruded
ell-contents and nuclei.

The third mode is known as "gemmiparous repro-

duction," and, as indicated by the term, multiplication takes place in this instance by a process of "gemmation" or "budding." A minute bud-like projection may be seen to form on the cell-wall, and this gradually developes itself, to form in due course, a new cell, which may remain connected to the original cell (Fig. 20, *n*) from which it sprang, or which may at once detach itself and enter upon a separate existence.

The last mode in which cells may reproduce themselves is by the process to which the name of "fissiparous reproduction" has been applied. This is the simplest, and also a very common form of cell-multiplication. A cell may be observed to gradually divide itself into two parts (Fig. 20, *d e f g*), and thus to form two new cells. It is then said to divide "fissiparously," or by "fission." The "nucleus" is thought by some authorities to be chiefly concerned in this mode of cell-reproduction, whilst others maintain that the process is merely a phase of the endogenous form of the reproductive process. It seems more correct, however, to recognise this latter as a separate form of the process, and also to note its essential feature, namely that of division commencing at the external margin or periphery of the cell. Finally, it is to be noticed that these methods of cell-reproduction are also represented in the reproductive functions of the animal and vegetable worlds; the entire organism in many instances thus reproducing its like after the same modes or fashions as its component parts.

The consideration of the primary origin of the cell-structures, the life-history of which we have just traced, leads us into the domain of controversy and speculation. Since the enunciation of the leading doctrines regarding the cell as the "anatomical unit" by Schwann and Schleiden in 1838, various theories of the nature and origin of cell-structures have been brought before the notice of the scientific world.

Schwann and Schleiden assumed the existence of a primary formative tissue, or "cytoblastema," in the substance of which minute granules were produced. These

ere supposed to develop into the "nuclei" of the future 'ls, and around each "nucleus" a membranous "cell-ll" was next said to be deposited; whilst the cell-ntents were believed to be gradually formed between e "nuclei" and the already formed wall of the cell. ie entire cell was thus believed to be formed in a adual manner, all its parts partaking equally in the rmative process, and no one part more than another ing considered the actual or potential formative centre.

To this theory succeeded the hypothesis advanced and pported by the late Professor Goodsir of Edinburgh. cording to Goodsir's theory, the "nuclei" constitute the sential part or "germinative centres" of the cells; and the aggregation of cell-structures, as indicated by their ode of development, a central cell is presumed to be the iginative progenitor of the other and surrounding cells.

By Huxley the origin of cells is traced from a primitive d structureless membrane or "blastema," in which vacuoles" or spaces are first produced; these vacuoles ucing a cellular structure, and containing each a cell-ll or "periplast," cell-contents, and nucleus or "endo-ast." The "periplast" or "cell-wall" is considered in is theory as the active source of all the formative and iginative changes to the cell.

By Bennett of Edinburgh, the cell, as a fully-formed ructure or organ, is considered as the result of truly iginative changes, preceding the formation of any of the rts which are accounted of primary reproductive power the foregoing theorists. Thus, according to Bennett, e minute "molecules" or "particles" of organic fluids 'ig. 20, *p r s*) are the *originators* not only of cells but fibres and membranes also. These molecules are sup-osed to possess both vital and physical properties of their n; and by their aggregation, and in virtue of these operties, complete and perfect cells, together with gher structures, are produced. This latter theory is cordingly known as the "molecular theory of cell-velopment and organisation."

Dr. Lionel Beale, whose microscopic researches have

deservedly won for him a high repute as a histologist and physiologist, maintains that to properly explain the origin of cell-structures, we must assume the existence of living matter in two states. The first state comprises "*matter that is in the living* state, germinal matter;" and, secondly, "matter that *was*, in the living state, formed material." The living material or "germinal matter" Dr. Beale considers to be the chief agent in the origin of cells. It may be regarded as most fairly corresponding to the active nucleus of the cell, and "by changes in the germinal or living matter," we are told, "the cell-wall, intercellular substance, and every kind of tissue, everything peculiar to living beings, results."

New cells, according to Beale, originate within the already-formed centres; whilst from without the "pabulum" or food enters the cell, and is vitalised by the "germinal centres" within. The first formed parts are thus gradually pushed to the external surface of the cell, and are farthest from the active "germinal centre." Matter so removed from this centre is considered non-living, or as having passed through the living state, and as having "had impressed upon it certain characters which it could not have acquired in any other way." Such matter, as has passed from the living to the non-living state, or from the central and germinating areas to the outer portion of the cell or organism, is exemplified in "the dried leaf, the lifeless wood, shell, bone, hair, or other tissue;" these structures thus constituting truly "formed" material.

The theory of Dr. Beale in part therefore agrees with that of Goodsir, in that both recognise the important and essentially originative nature of the "nuclei." Beale, however, further extends his ideas and generalisations to include the latter stages in the history of the cell, and thus enforces his distinction between the "living" nuclei or "centres," the "pabulum" on its way to become living matter, and the external or outer portions of the cell, which have already been vitalised, and which are now "non-living" material.

The theory of a "physical basis," lately advocated by Huxley, like the molecular theory of Bennett, seeks to trace the origin of the cell and of living tex. res to a period prior to the formation of any of the struct ral elements of the cell. The nature of this "protoplasm" or "physical basis of life" we have already examined, and it only remains, in concluding the present chapter, to say a few words regarding the more important of these theories, and also to notice a few of the more special aspects and relations of "bioplasm" to the living organism.

Regarding the ultimate histological constituent of the living organism, there can now be little hesitation in discarding the idea that the cell represents the initial stage of the process of organisation. Indeed, the many and wide variations observed in the modes of cell-development, and in the sequence in which the several structural parts of the cell are evolved in different cases, would alone convince us, or would, at any rate, lead to the belief, that a prior state of community in organisation exists. This prior state is found, according to the latest research, in the molecular particles, with their inherent and associated vital and physical properties; or in the protoplasmic "basis," which, by subsequent differentiation, may produce the several structures of which the living body is composed.

If now we direct our attention to the relative merits of each theory, we shall be somewhat puzzled to pronounce a decided verdict in favour of either. Each hypothesis serves to explain certain features in the preliminary stages of organisation, which the other appears to take no cognisance of; and hence, whilst we can hardly consider either theory to be of itself perfectly explanatory of the conditions necessary for the first manifestations of vitality, we may yet find them, mutually and together, equal to the task of accounting for the preparation and organisation of a true and consistent life-basis. Thus we may, consistently with both theories, form the idea of a "molecular bioplasm"—the bioplastic matter serving as the primary medium and basis, through which the "mole-

cules," as the more active centres of vital activity, evince their tendency to evolve higher structures and parts. This condition of a "molecular bioplasm" will also serve to account for those conditions, hitherto inexplicable by either theory alone, in which molecular activity seems to take origin and keep pace with the bioplastic or protoplasmic development.

Both molecules and bioplasm are thus distinctly "vital;" both possess the same inherent "vital properties," in virtue of which physico-chemical action is made subservient to the purposes of vital growth and development. But it is impossible to assign to either bioplasm or molecules the priority in appearance, or in the exhibition of active and vital phenomena. In all probability we shall have to assume the essential and primary state of living matter, as represented by a basis, the active centres of which are truly molecular. The molecules, equally with the bioplasm, appear as units and ultimate quantities in the operations of vitality; and we can best conceive the probable relations of these quantities as those of two distinct conditions of vital materials, derivable from a common and anterior source, and exhibiting a conjoined action to produce a common result. And, lastly, beyond either molecules or bioplasm, but guiding, and, in all probability, also producing and creating these primary forms of living material, we find the subtle force or vital principle, which organises, manifests, and directs all the powers and actions of the living body, both in its most primitive and unorganised state, and in the highest phases to which its existence may proceed or be developed.

Throughout our subsequent investigations into the manner in which the great vital processes are carried on within the living organism, we shall have occasion to notice the important aspects in which both bioplasm and cells are related to the functions of life. And the considerations herein offered will be found of service in aiding us to more clearly comprehend the essential and characteristic actions and phases involved in the development and maintenance of the living body.

CHAPTER X.

Physiology of the Living Organism—Function of Nutrition: its Nature and Relations to Tissue-waste—Nutritive Equilibrium and Excess—"Growth:" Nature and Phenomena of—Nutritive Deficiency—Atrophy—Hypertrophy—"Death" as a result of impaired Nutrition—Food of Animals and of Plants—Process of Assimilation: its Nature and Relations—Function of Innervation—Essential Conditions of Correlation—Correlation in the lower Forms—Nerve-tissue in the lowest Organisms—Views of Beale—Innervation in Invertebrata and Vertebrata—Phenomena of "Instinct."

THE function of *Nutrition*, or that by which a living being nourishes itself and contributes to its growth and increase, forms, in the most appropriate manner, the first of the great vital processes which we are, in the present instance, led to consider. The first act of the newly-formed being is nutritive in its character. Its first instincts are directed to the prehension of the matter necessary for the sustenance of life, and to the due maintenance of the nutritive process the function of correlation or innervation may be said, in the first instance at least, to be wholly devoted. As we shall afterwards more particularly observe, the third great function, that of reproduction, is in its nature antagonistic or opposed to that of nutrition; the preservation of the species being, in this way, more or less antagonistic to the preservation of the individual.

We have already remarked that the mode of increase of a living being is invariably associated with the "intussusception" of material from the outer world, or, in other words, with the reception within its body, of matter derived from the medium in which it lives, or with which it is connected. This material we ordinarily know as "food," and the special functions which are respectively

devoted to its prehension, and ultimate "assimilation," are collectively denominated under the general term of "nutrition."

The living organism, in the exercise of those functions, or in the performance of those acts which depend on the presence and possession of vitality, is constantly subject to a greater or less waste of substance. The slightest or most simple action on the part of a living being involves a corresponding loss of vital power, which is manifested by a subsequent and proportional destruction or waste of the textures and tissues of its body. This waste necessitates renewal and repair; and, in this sense and aspect, the vital organisation approaches most nearly that of the mechanical. Just as the machine requires certain conditions, such as those of fuel or applied force, to sustain its mechanical powers, so does the living organism require its own and special conditions to enable it to successfully maintain and renew its vital powers. The failure of the requisite supply of conditions to the machine results in its disorganisation, or simply in the cessation of its functions. The failure of the nutritive supply of the living organism is attended by the same result, manifested, however, in a much more striking degree—namely, in that of complete disorganisation, cessation of vital power, and finally of "death."

At this stage, however, the parallelism between the mechanical contrivance and the living organism may be said to cease. The machine can, of itself, give no outward or visible evidence, or sign, of its wants; it possesses, *per se*, no knowledge of conditions or sensations, and the failure of the necessary conditions would be indicated simply by the stoppage of its mechanism, and by the cessation of its function. But the living organism, in virtue of its vitality, possesses the power not only of giving evidence of its wants, but is also furnished with the means for satisfying these demands; and it moreover possesses the power of elaborating from "raw material" the matter necessary for the nutrition and repair of its body.

Hence the term "nutrition," used after the purely de-

velopmental and earlier phase of the function has been subserved, may be regarded as synonymous with that of "repair;" the function of nutrition in the living organism being thus devoted to the repair and renewal of the tissues after the wasting and destruction dependent on the performance of their appropriate vital functions.

The general term "assimilation" has already been used to denote the more typical phenomena included in the performance of the nutritive function; and the present chapter has for its object the cursory review of these phenomena, and of those less notable actions which spring from or are dependent upon them.

The first observation to which attention may be directed lies in the fact that the living organism appropriates to itself matter from the external world, and of a kind generally foreign to itself, but which it converts, by the assimilative process, into the materials of which its body is composed. There is thus a subtle conversion of material of one kind into material generally of a widely different kind; and, in the performance of this process, organs or tissues varying widely in structure and complexity are engaged.

We have previously noticed, in treating of the "specialisation of functions," that the highest and lowest organisms each nourish themselves after the most perfect fashion, but differ in the manner in which the process is effected. The nutritive function is thus perfectly performed by every organism, whatever its rank in the scale of creation; but in its performance a great variety of means, varying in complexity, is employed. The Amœba (Fig. 1), by means of the nearly structureless protoplasm of which its body is composed, performs the nutritive function, and renews and repairs the waste of its body as perfectly to itself as does the Mammal (Fig. 11), with its complicated digestive system. The difference between these forms, or between all the varying forms of which the organic series is composed, does not therefore concern the *result to the organism* of the nutritive process. Every living being manufactures from its "food," in the most

perfect manner, the material or materials necessary for the sustenance of its life.

We thus reduce to a striking community of type or detail the aim of the nutritive function throughout the organic series; and this ultimate aim is the formation or elaboration from the food-material of a fluid varying in composition, but containing certain nutritive principles, from which the tissues in turn draw their nutritive supply. This nutritive fluid in the higher forms of animal life we know as the "blood," whilst in plants it receives the general name of "sap."

A further consideration of the preceding points will show us that the process of "assimilation" in the living organism, and viewed relatively to the constituent parts of the organism, has a twofold aspect or nature. We find, firstly, the primary process of "assimilation" performed by the organs of digestion; this first process resulting in the manufacture, production, and circulation through the body of the nutritive fluid. This fluid forms the common source whence the nourishment of all the varied tissues of an organism is derived; and hence we recognise the existence of an ultimate or secondary process of assimilation—that of "assimilation" by the respective tissues of the organism, whereby each tissue, from the nutritive fluid, in turn elaborates the special materials necessary for its own and intimate repair. Thus it is, that from the common "blood" conveyed to the tissues of the higher animal, bone-tissue manufactures or renews its own peculiar substance; that nerve-tissue assimilates nervous substance; that muscular tissue manufactures muscle; and that every other tissue forms and elaborates its peculiar substance from the common nutritive fluid, just as this fluid was previously elaborated or manufactured from the food.

A series of actions so remarkable as those involved in the process of secondary assimilation or digestion by the tissues, has afforded, as might readily be expected, matter for much thought and speculation at the hands of physiologists; and to the vital property in virtue of which

living structures possess this wondrous power, the various terms of the "vital property of attraction," or "selection," and the "elective affinity of the tissues," have been applied. The exact nature or *rationale* of the process remains hidden from the furthest research, but we may safely assume its intimate dependence, with many other and similarly subtle processes, upon the possession of "vital force," vitality, or life.

The living organism, then, by means of this twofold process, nourishes itself as a whole, and also sustains the life and vitality of its more intimate and distinct constituents. The act of living or of being, involving motion and the exhibition of force, is accompanied, as already remarked, by a corresponding amount of tissue-waste. Loss of power is thus invariably accompanied by loss of substance; and it is this loss of substance which necessitates the repair, primarily, of the body as a whole, and secondarily of the tissues. So long as the reparation of the tissues keeps pace with the tissue-waste the organism will maintain itself in a state of nutritive equilibrium. Notwithstanding the incessant loss of material, and the equally constant repair, the organism as a whole will present a comparatively unaltered appearance and conformation. But it is conceivable that the nutritive supply may exceed the tissue-waste, and in the earlier periods of existence this relation between the nutritive waste and repair actually occurs. In the young organism the process of nutrition is more than adequate to compensate for the comparatively trivial tissue-waste of early life; and new material being thus added to the body faster than it is expended, we find the tissues, and, through them, the entire organism, increasing in size, or exhibiting in this way the process and phenomena we familiarly know under the name of "growth."

"Growth" thus essentially implies nutritive excess—the addition of nutritive material, and the increase of tissues, of organs, and of the entire body, at an increased rate when compared with that of the nutritive expenditure. This much is meant by "nutritive growth;" but

we may distinguish a second kind of "growth" which does not consist in the increase of already-formed tissues, but in the formation and advance towards maturity of new structures or parts. This latter process, witnessed in the earlier phases of the existence of a living organism, has reference to the *development* of the being; and hence it may appropriately be termed a process of "nutritive development" or of "developmental growth." The conditions and phenomena of this latter phase of the nutritive process will be hereafter investigated under the subject of *Development*.

The balance of waste and repair in the living organism, and the maintenance thereby of the body in a state of nutritive equilibrium, must, however, be viewed in contradistinction to a second and opposite condition—that of nutritive deficiency. The conditions of waste and repair being equal, the living organism maintains a natural and stable position with regard to its own and intimate functional relations, and with regard to the world in which it lives. But if we suppose that the nutritive supply falls short of the demand, we then find the organism to exhibit a corresponding loss and diminution of vital power; and if the deficiency be carried out to a great extent the death of the organism from "inanition" will result. This result, therefore, concerns the being or body as a whole, but the occurrence of "local" or "partial" death is also to be noticed. This latter phase has reference to conditions of nutritive deficiency, where a limited portion of the organism only, such as a tissue or organ, is affected. The deficient nutrition of such a part produces the death or deterioration of the organ, and it may thus die or become functionally useless so far as the organism as a whole is concerned. And hence the organ or part is said to be locally dead; or when deteriorated by deficiency of nutrition, or by want of functional activity resulting from inefficient nutritive supply, the structure is said to be "atrophied."

Nature not unfrequently is observed to induce the occurrence of "atrophy," by cutting off the nutritive

supply in parts or organs which are no longer required in an animal economy. Thus, at birth, many embryonic structures atrophy and disappear from this natural cessation of nutrition; the process being induced primarily, no doubt, by such organs being no longer required in the discharge of the newly-assumed functions of the being. And similarly in old age the same process of atrophy appears to affect organs and parts, and indeed the body as a whole; although the intimate causes of this "senile atrophy," as it is called, are less susceptible of explanation than those of the ordinary phases of the process.

Nutritive excess, carried to a great extent in consequence of excessive functional activity, or in virtue of other causes, is also liable to induce a condition opposite to that of "atrophy," and known as "hypertrophy." Excessive use of an organ, necessitating increased nutritive supply, is commonly associated with an increase of structure beyond the ordinary and normal limits. When an organ is influenced by such conditions, the result is a "hypertrophy" of the organ or part. "Hypertrophy" is thus merely "nutritive excess" induced to a high or extended degree by the increased use or functional activity of a part, and it may therefore be regarded as simply a form of abnormal "growth."

Lastly, and in concluding these general observations on the process of nutrition, we may refer to the ultimate effect of prolonged activity on the nutritive function, and to the effect of such a condition on the body as a whole. We have previously remarked on the result of the premature failure of the nutritive function; a result synonymous with the "death" of the organism. And it has also been observed that the process of tissue-waste may be regarded as essentially one of "local death." But a consideration of the cycle of existence in the living organism shows us that a certain [illegible] inevitably ensues in its life-history when the nutritive as well as the other functions of the body appear to fail in administering to its wants, and when, as a result, the vital activity of the being entirely and for ever [illegible]

Through this consideration we are led to notice the occurrence of this cessation of vital activity in an organism, simply from an apparent deficiency in nutritive power. Apart from the occurrence of abnormal or diseased states or conditions, we have therefore to observe the fact of death occurring naturally, or from a defective nutrient supply. And when we might be tempted to suppose that this latter result is in itself unnatural, it is to be borne in mind that the period of existence in the living organism appears to be bounded by certain limits, not always to be defined it is true, but sufficiently well marked to leave no doubt of their existence.

In virtue of the fact that the existence or life of the living organism is a cycle, repeating itself in all the functions which pertain to the vital state, we may safely assume it as a natural result that, like an ordinary piece of mechanism, the living body should sooner or later wear out and become incapable of further performing its functions, whether these be comparatively simple or intricately complex. And as the parts or organs of the machine become deteriorated by the wear and tear of its work, so the organs of the living organism become affected by the incessant effort of living and being. Why this should be so, physiological science does not pretend to explain; but we may, with all safety, assume that the conditions determining the limits of existence are, like those which regulate the causes of that existence itself, beyond the bounds to which our furthest light and investigation extend.

The relative nature of the food of animals and plants has already been pointed out, and but little remains to be noticed under this division of the subject. The food of plants we have seen to be composed in chief of inorganic materials; and these substances the plant, by its constructive chemistry, is capable of elaborating into compounds of organic nature. The inorganic food-materials of plants are chiefly carbon, nitrogen, oxygen, and hydrogen; these substances being derived respectively from the carbonic acid of the atmosphere, from the

ammonia of the soil, and from the water they absorb. These inorganic compounds are converted within the plant-organism into organic compounds of highly complex nature.

Animals, on the contrary, demand for their due sustenance a supply of already elaborated nutritive or organic material; and this material they obtain chiefly from the plant world. The animal, equally with the plant, possesses a vital chemistry peculiarly its own, and by aid of this chemico-vital action it converts the organic into inorganic material. In connection with the food of either series, we have to notice the general occurrence, as part of the dietary of animal or plant, of certain inorganic or mineral substances. Of these, some few appear almost, if not absolutely essential to the nutrition of the organism, whilst they all bear an important part in its histological or intimate composition. Such inorganic substances as the various salts of lime, silica or flint, iron, phosphorus, etc., appear to enter into the intimate composition, and otherwise to be closely bound up with the nutrition, of the living organism.

To the above broad and general facts and laws regulating the relative nature of the food of animals and plants, there appear certain exceptions, of which it is necessary to take cognisance in the present instance. Thus certain of the lower plants, or Fungi, appear to subsist chiefly, if not entirely, upon organic compounds; living parasitically upon other plants, or upon animals, the substance of whose bodies they appropriate to their own and special nutrition. And in their reaction upon the atmosphere they do not appear to emit oxygen, as is the case with ordinary plants. Conversely too, certain of the lowest forms of animal life—such as the deep-sea Foraminifera—appear to be capable of subsisting upon inorganic materials, and so to imitate the members of the plant series; whilst such forms have been also supposed to present exceptions to the ordinary rule of animal existence, in that they inhale carbonic acid and emit oxygen. But the validity of these latter suppositions appears to

be rendered doubtful from the consideration of more feasible explanations of the conditions of life in these deep-sea forms; which conditions will be more appropriately referred to under the head of "Distribution in Space."

In considering very generally the actual details of the nutritive process, we find it divided into the subsidiary processes of prehension; mastication; insalivation; digestion; absorption; assimilation of the absorbed products of digestion; circulation of the nutritive fluid or blood; nutrition of the tissues; excretion from the tissues; and respiration or the purification and aëration of the blood—that is, the excretion from the body of the substances evolved from the tissue-waste, and the simultaneous absorption of fresh oxygen into the nutritive fluid.

In animals we find the food-material received within the body, and generally an internal cavity or stomach is the seat of the essential changes and primary stages in the elaboration of the nutrient matter. Even in the lowest organisms, such as the *Amœba*, we find the function of prehension subserved by the finger-like processes into which it is capable of pushing out its protoplasmic body, and the little particle of food is received within the soft jelly-like mass, and is there subjected to the digestive process. A little clear space is then seen to form around the food-particle, and gradually it appears to be dissolved and incorporated with the contents of the body. In this case digestion, assimilation, and absorption are performed at once and by the same process; which, simple though it may appear, yet partakes, equally with the highly complicated process of the mammal, of the subtle and mysterious nature of a truly vital action.

The process of digestion, or, to use the wider term, of assimilation, is therefore to be regarded as essentially and primarily *vital* in its nature. That many changes occur in the process of elaboration of food into a nutritive fluid, which are explicable on chemical grounds and conditions, cannot be denied: but to assert that the entire action is merely one of chemical separation and re-formation, is to

state what is as far from the truth as to say that there is no chemical action whatever. The chemist, for example, may make us acquainted with the *modus operandi* and results of the influence of solar light upon the functions of plants; but his explanation will leave us as ignorant as before of the more intimate causes or forces from which the very actions he describes take their origin. There is, therefore, a something in the vital actions of plants and animals which a mere chemical theory will not suffice to explain. Chemistry, it is true, will explain for us the *conditions* under which many of the functions of the living body are exercised. Of such conditions it takes due cognisance, and may further elucidate the manner in which they relatively combine to effect a given result; but it does not follow that, although we gain a perfect knowledge of the conditions under which an action may take place, we are also, and at the same time, conversant with the *causes* which give rise to the conditions. The solar beam may thus represent the conditions necessary for the due performance of plant-functions, but of the intimate changes and actions which the plant effects in turn upon the sunlight, chemistry can give no explanation. For, if we are to denominate such actions as purely chemical in nature, there will, even after such an admission, be many points and phases which render these actions entirely different from, and unlike, any processes with which the chemist is acquainted. Such an admission would thus involve the chemist in the difficult position of being unable to account for or explain phases, which, at the same time, he admits to fall within the province of his science. And unless we assume the existence of some other force inherent to, and manifested solely by the living organism, we shall have to leave the question at issue as one which does not admit of any feasible or competent explanation.

Hence, in discussing the probable cause of this and other vital actions, we must bring to light and reproduce the same arguments and considerations which we have already enumerated in investigating the subject of "life" and

specialised, generally possess, as already remarked, a rudimentary or general circulation of the fluids contained in the cavity of the body; this circulation being excited and maintained by the action of the minute, vibratile, eyelash-like filaments, known as "cilia," which very generally fringe the surfaces of the internal membranes throughout the animal series.

The function of respiration is performed generally by distinct organs, known as "lungs," and as "branchiæ," or "gills;" but it may be subserved, as in *Flustra* (Fig. 6), by the tentacles or organs of prehension. In other cases respiration is performed by the ciliated surfaces of the body-cavity, or by the general and external surface of the body. In any case, the absorption of oxygen gas, and the excretion of carbonic acid gas, are the characteristic features in the performance of this function by the animal. The function of respiration in plants is performed by the leaves; carbonic acid gas being, in the case of the plant, absorbed, whilst oxygen is exhaled.

The function of respiration ranks, in point of frequency of occurrence throughout the animal series, next to that of the actual prehension and digestion of food. Even in such forms as the *Amœba* and its allies, there appears to exist a process imitative of the renewal of oxygen in the higher animals; and from the intimate connection between the processes of circulation and respiration, it appears highly probable that the two processes may, in these [illegible]er organisms, be subserved by one and the same [illegible]. In this way, the "contractile" vesicles of the [illegible] *Infusoria* (Figs. 12, A *b*, and 22 A, *c c*), may [illegible] equally subserve the circulation of fluid, [illegible] aërating medium. And in such [illegible] to [illegible] with very [illegible] this [illegible] wondrous cycle of functional manifestations.

Digestion in the stomach or gastric cavity is, in the higher forms, succeeded by digestion in the intestines, to which latter process succeeds the absorption of the elaborated fluid from the alimentary tract, by a distinct set of

beginner in zoological studies a broad, but, at the same time, essential and necessary idea of the mode in which the organisms he will meet with in his systematic studies nourish themselves, and of the manner in which the chief and most apparent processes of life are subserved throughout the animal series. It only remains, in the present case, to say a few words concerning the function of *Innervation*, since we reserve the consideration of the *Reproductive* function for a separate chapter, and for a subsequent period in our biological studies.

The function of *Correlation*, *Innervation*, or *Irritability*, has already been defined as that whereby an organism maintains relations with its fellows, and with the medium in which it lives. The present function is one which has been thought to be essentially peculiar to the animal series. And the functions of relation have accordingly been denominated the "animal" functions; whilst those of nutrition and reproduction, from their community in both plants and animals, are commonly spoken of as the "organic" or "vegetative" functions.

Whilst, therefore, the correlative process is one which is seen to fullest perfection in the animal series, there is good reason for the belief that plants also possess means for maintaining relations with surrounding media, and this in a manner closely analogous to that observed in many animal forms. And when we reflect that in not a few organisms—exemplified by the entire *Protozoa*, and most *Cœlenterata*—the truly animal nature of which cannot be questioned, no distinct or specialised apparatus for carrying on the function of innervation can be discerned, we must admit that the limitation of the function to the animal series is, on reasonable grounds, to be considered as somewhat of an arbitrary nature. Such animal organisms, as are above indicated, despite their want of specialised or distinct nervous centres, exhibit many of the phenomena which we regard as normally taking origin from, and as regulated by, a correlative apparatus. The phenomena of co-ordination of motion, of contractility, and many other processes, which, in the higher forms of

animal life, we know to be dependent upon the operation of the innervative function, are also perfectly exhibited by many of these lower forms. Hence we are led to the belief, firstly, that the phenomena of correlation may apparently be dissociated from a specialised nervous system; secondly, that the specialisation of this function does not partake of that gradual development which we have seen to be characteristic of nutrition and reproduction; and, thirdly, that the innervative process appears to be subserved in the lower forms of animal life and in plant existence generally, by an adaptive or functional development of the ordinary tissues and textures of the body.

The advance in the histological department of morphology, and the close application to, and improved methods of, microscopic research, may in the future enable us to determine with exactitude the curious relations between the function of innervation and the organism in which it resides. Recently, Dr. Lionel Beale has suggested the idea, that not only are means for the performance of the correlative function invariably present in the animal organism, but these means may, in the hands of the skilful microscopist, be traced out to actual demonstration. Thus he tells us that "it might be supposed that we should be able to form a correct idea of the essential structure of a nervous apparatus if we appealed to some of the lowest organisms in which the existence of nerve-tissue might be fairly assumed. In them it would be supposed that we should meet with a nervous system in a very simple condition. But it unfortunately happens that in these lower forms of life the nerve fibres are so very delicate as to be, under ordinary circumstances, invisible. Nor is it surprising that the difficulty of detecting them has induced some to adopt the hasty and, it must be admitted, unjustifiable inference, that many creatures which exhibit combined and complex muscular movements are altogether destitute of nerve-fibres, but that the nerve matter of their bodies exists in a diffused and fluid state, or in the form of minute disconnected particles disseminated amongst the tissues.

"Now, if the tissue of the arm of an Actinia, or sea-anemone, be carefully examined after successful staining, multitudes of minute oval bioplasts (nuclei), taking different directions, will be observed amongst the muscular fibres, as well as in the external investment. The disposition of these would receive explanation if they were connected together by delicate threads. Here and there, in a very thin specimen, a very delicate film can indeed be discerned passing from one bioplast to its neighbours. . . . . In the peripheral organs of the perfect fly, and in many tissues of the mollusca, especially over some of the muscles, I have been able to separate an extremely delicate tissue, consisting principally of nerve-cells with very fine fibres passing from them, and crossing and interlacing in every direction, constituting what may truly be described as a nerve membrane of extreme delicacy. We shall find in the peripheral parts of the nervous system of man and the higher animals at an early period of development, a precisely similar arrangement. In this delicate membranous structure no separate nerve-cords or fibres can be detected, but delicate tracks crossing one another at various angles may be discerned."

The view thus promulgated is further detailed, with the object of showing that, in all probability, the nervous power, in virtue of which the function of correlation is manifested, may be regarded as an original property of the "protoplasm" or "bioplasm" of which the living organism is composed. And hence Dr. Beale believes in the community of type of nerve-force, as exhibited in the lowest or in the highest organism; this common nature taking origin from the community of the living "bioplasm," in which this nerve-force or correlative power is originally inherent. Thus he says—"Although, therefore, the nerve-current may be due to chemical change, and the arrangement of the nerves might be accounted for by physical actions, both series of phenomena are dependent upon antecedent operations which must be at last referred to the direct influence exerted by the peculiar power which is associated with the matter of the bioplasm during its

living state." And, again, a nervous apparatus is to be regarded "as consisting essentially of fine fibres and masses of bioplasm, which form uninterrupted circuits." And lastly, regarding the primary origin of the nervous system, as affecting the question of its actual presence and form in the lowest organisms, Dr. Beale says, "the formation of the nerve-fibres and cells—the construction of the nerve mechanism, must be referred to the properties or powers of the bioplasm which preceded its formation. The *action* of the mechanism may be said to be due directly to physical and chemical change, but the matter which is changed, it must be borne in mind, was formed by bioplasm, and owed its origin to bioplasm. The higher phenomena of the nervous system are probably due primarily to the movements of bioplasm, by which some part of the nerve mechanism is acted upon."

The ingenious theory thus expressed, may, for the present at any rate, afford an explanation of the occurrence of correlative phenomena in the lower forms of animal life, which has the merit of resting upon a demonstrable basis. And if we accept the main thought of this view, we may form some conception of the mode and means by which an organism—such as the *Amœba*—whose body consists wholly of bioplasm in its simplest possible state, maintains relations in its economy which are undoubtedly analogous to those we are accustomed, in the case of the higher organism, to associate with the possession of nervous centres. In this way, also, we can conceive a probable idea of the non-specialised nature of the nervous apparatus in the lower forms; the progress of specialisation tending to gather together and to concentrate the bioplastic nerve-centres, until, progressively, the highest form of a nervous apparatus is produced.

The essential feature in the function of *Correlation* is the reception by the organism, through its correlative apparatus, of certain impressions derived from the external world, and known as "sensations." These impressions or sensations, through the medium of its nervous system, influence the individual parts of the organism, or the

organism as a whole; and it is thus enabled to re-act upon the media by which it is surrounded. Or, if we state the case in the reverse order of its circumstances and phenomena, and start with the influence of the organism upon the external world, and the reaction upon the organism of external media, the result, to the media and to the organism, will be exactly similar in every way.

The reception by the organism of "sensations," and its reaction upon the medium from which the sensations are derived, therefore constitute the essential and characteristic features in the operation of the correlative function. And in the lower or *Invertebrate* forms of animal life the nervous apparatus may be considered to be almost wholly occupied in the reception of the ordinary "sensations," which minister to the wants and necessities of existence, without any active or intelligent appreciation of the causes or results of the sensations thus conveyed. Or, to use the words of Dr. Carpenter, "the type of psychical perfection among Invertebrated animals, which is manifested in the highest degree in the Social Insects, consists in the exclusive development of the *Automatic* powers, in virtue of which each individual performs those actions to which it is directly prompted by the impulses arising out of impressions made upon its afferent nerves, without any self-control or self-direction; so that it must be regarded as entirely a creature of necessity, performing its instrumental part in the economy of Nature from no design or will of its own, but in accordance with the plan originally devised by its Creator."

In the *Vertebrata*, on the other hand, we find the higher perfection of the correlative apparatus associated with powers which place the organism far above the rank and relations of a piece of automatic mechanism. And we accordingly notice this specialisation of the correlative powers in these higher forms, evincing itself in the possession of a power of appreciation of the origin of sensations, known as "intelligence;" whilst, in virtue of this latter feature, we find another and distinctive power super-

added, which is devoted to the regulation of the movements of the body, and which is known as the power of "volition" or "will."

Such a development of functional powers and attributes is accompanied by a corresponding specialisation of the nervous centres; and accordingly we observe the correlative apparatus of the Vertebrate to evince a division into distinct parts, each part having to deal with special processes in the performance of the correlative function. The "cerebro-spinal axis" of the vertebrate (Fig. 11), consisting of the brain (*b c*) and spinal cord (*s s*), thus constitutes the chief nervous axis of the body. The brain, or collection of nerve-centres, or "ganglia," is the seat of those directing and guiding powers which raise the vertebrate above the lower or invertebrate forms; whilst the "spinal cord," or continuation of this chief nervous centre, forms the medium through and from which the nervous supply of the body generally takes origin, and along which the guiding impulses of the brain are transmitted to the various organs or parts of the system. And, lastly, from the brain and spinal cord the various nervous trunks arise, and are distributed throughout the body.

In addition to this chief nervous axis we find a second series of nerve-centres present in Vertebrata. This latter system has been denominated the "sympathetic" or "ganglionic" system of nerves (Fig. 11, *p p*), and consists of a chain of "ganglia" or nerve-centres disposed along the under surface of the spinal column, and connected with the "cerebro-spinal" axis. The operation and regulation of this latter system of nerves is, to a great extent, independent of, and without the influence and command of, the will. The functions of the "sympathetic" system appear to be those of regulating the movements and processes of digestion, circulation, and respiration, and of influencing the various secretions connected with these processes.

In *Invertebrata* the nervous axis generally consists of a series of nervous centres or "ganglia," arranged after various fashions, and connected together by nervous cords

or bands. Such a system, whilst it may be shown to be partly homologous with the "cerebro-spinal" axis of the Vertebrata, nevertheless corresponds in general function to the "sympathetic" system of the latter forms. The *Invertebrate* apparatus of correlation may therefore be regarded as a general medium for the regulation of the vital processes of the body, together with the administration of the correlative power necessary for the functional exercise of the organs of sense, in cases where these are present. The "excito-motor" movements of the Invertebrate, together with those which, from their affecting the organs of sense may be termed "sensori-motor," are essentially and solely of an automatic kind; since, however perfectly adapted to surrounding circumstances these movements may be, they want the directing and guiding intelligence of the higher forms.

In *Invertebrata*, accordingly, the nervous axis may be regarded chiefly as constituting a mere connecting and controlling medium to the various parts of the organism. Its various centres may be regarded as semi-independent factors in the constitution and performance of the correlative function. In the *Vertebrata*, on the other hand, the process of specialisation tends to develop as chief and independent factors, certain parts of the nervous axis; these latter parts serving, as we have seen, to direct and control, in virtue of an inherent intelligence, all the functions and processes of the organism.

The occurrence amongst certain Invertebrate forms—typically exemplified by the "social" insects—of a remarkable development of apparent intelligence, directing and guiding the special impulses of these creatures, is entirely and satisfactorily explicable according to the ordinary facts and laws which regulate the correlative function in the Invertebrata as a whole. This adaptation of action to special ends, we ordinarily know as "instinct;" and the exhibition of this power or phase occasionally includes phenomena of the most remarkable kind, which would, at first sight, seem to be suggested, directed, and controlled, by the operation of an

animated intelligence analogous to that which controls the operations of the higher and Vertebrate form.

The phenomena, for example, which are noticed in the performance of the many and complicated functions that make up the life-history of the ant, wasp, or bee, and the consideration of the wondrous exactitude with which their many labours and duties are performed, would, and not unnaturally either, almost force upon us the impression and belief that this so-called "instinct" must be nearly allied in nature to the higher powers of reasoning and of intelligence. Yet the most marvellous exhibitions of instinctive powers simply consist of movements induced chiefly by external impressions—"sensori-motor" movements—but in which neither reason nor intelligence, as evinced in the higher animals, participate.

The wasp, ant, or bee thus constructs its abode, and performs the duties incidental to its highly-organised existence, primarily, as a result of the "adaptive" nature of their nervous organisation; the surrounding circumstances of the insect's life being the undoubted and exciting causes of the "sensations," and through these latter of the "movements" which together make up the cycle of "sensori-motor" or "instinctive" acts. And this assertion receives support from the mere circumstances and essential conditions under which the instinctive power operates. Thus the same series of actions and labours is undertaken and performed by all the members of the colony, or by the entire species; a community of impulse being thus associated with a similarity of conditions. And the insect may therefore be compared to a highly-perfect piece of automatic mechanism, which derives its impulse from the conditions by which it is surrounded, and which invariably executes or performs the same round or cycle of duties with an exactitude due simply to the harmonious and unaltering nature of the surrounding media.

And similarly with the relations of instinct to the educative power we familiarly know as experience. The higher organism progressively, and through the teachings and instructive power of experience, attains from im-

perfections in the performance of duties and labours to their due and perfect execution. Its progress, influenced and carried on by its high psychical development, is necessarily at first of a slow and gradual character; but, once having attained to the knowledge and execution of the task, succeeding efforts will only tend to further improve or perfect the knowledge which has thus been acquired. Not so, however, with the form which performs its duties in virtue of the possession of merely instinctive powers. The bee or wasp, after arriving at maturity, at once enters upon the performance of the most complicated duties, without any previous knowledge or educative effort; and the task or labour will be none the more perfectly performed at the close of existence, and after countless repetitions, than it was at the commencement of active life. The bee, similarly with the automatic machine, thus requires no preliminary education or experience, but enters upon its duties at once, and as naturally as the mechanism of the machine, once perfected and set in operation, fulfils the function for which it was destined and prepared.

And, lastly, as remarked by Dr. Carpenter, "the very perfection of the adaptation, again, is often of itself a sufficient evidence of the unreasoning character of the beings which perform the work; for, if we attribute it to their own intelligence, we must admit that this intelligence frequently equals, if it does not surpass, that of the most accomplished Human reasoner."

The phenomena of contractility and movement of the leaves observed in many plants have been referred to in commenting upon the apparent limitation of the correlative function to the animal world. Such movements are witnessed in widely different degrees of perfection throughout the vegetable world; those observed in the *Mimosæ* or Sensitive plants, in the Venus' Fly-trap (*Dionæa muscipula*), and in the Moving Plant of India (*Desmodium gyrans*), exhibiting the phenomena in their most typical aspect. The leaves in the first-mentioned plants exhibit a high degree of irritability; the slightest touch or irritation

causing them to exhibit the movements of folding in and of drooping the irritated organs. Whilst in the Venus' Fly-trap the surface of the leaf-blade is provided with sensitive hairs, which, on being touched or irritated, appear to cause the closure or folding-together of the two halves of the leaf-blade. In the Moving Plant of India, the individual leaflets of which the leaf is composed exhibit a constant oscillatory movement, and in this way they are seen to wave from side to side, and also from above downwards.

The seat of these movements appears to exist in cellular nodes or swellings situated at the base of the leaf-stalks or "petioles" in the sensitive plants; the sense of irritation being apparently conveyed by these sensitive expansions to the cellular structures of the plant. By botanists the cause of these movements is therefore referred to the contraction and expansion of the cells and cell-contents; and although such an explanation might account for the purely mechanical movement of the leaves, there yet remains to be elucidated the nature of the conditions in virtue of which the cells become thus sensitive to the action of stimuli. The inference, that these conditions may take origin from the presence of a correlative apparatus of a lowly-specialised nature, does not, in the face of the considerations previously enforced, become of an improbable or unwarranted nature. And recent physiological researches—among which those of Dr. Pettigrew stand conspicuous—have given to this latter opinion a nature and status above that of a merely hypothetical statement.

CHAPTER XI.

Nature of the Reproductive Function—Various Forms of the Process—"Sexual" and "Asexual" Modes—"Sexual" Reproduction—"Asexual" Methods—"Gemmation" or "Budding," and Fission—Examples of Fissiparous Reproduction—Illustrations of "Gemmation"—Internal and External Gemmation—"Alternation of Generations," or "Metagenesis"—Illustrations of "Parthenogenesis"—Antagonistic Nature of Reproduction and Nutrition.

THE function of "Reproduction," and its concomitant phenomena, constitute one of the most important phases of which the cycle of existence in a living being is composed. And the present function differs materially in its mode and period of operation, and in its effects upon the organism, from those other vital processes which minister respectively to the nutrition and innervation of the living form. The process of "Nutrition" provides for the due repair and sustenance of the being. It is manifested throughout its entire existence, and is more or less constantly in operation and activity. The function of "Innervation" partakes in nature much of that of the nutritive process. It is similarly exerted and exercised from the earliest period of existence to the close and cessation of life; and, conjointly with the previous function, acts and operates in the preservative and nutritive interests of the organism. Very different, however, are the aspects in which the function of "Reproduction" must be viewed. So far from being exercised throughout the whole life of the organism, we find it in operation during a very limited portion of that existence; and in most cases, only when the mature and adult stage of life has been attained. In its duration and period of activity it is similarly inconstant; and

finally, instead of contributing to the nutrition of the organism, or aiding in the regulation of its body, we find that the reproductive function tends essentially to detract from, or even impair, the energies of the form; so much so, indeed, that in some cases the existence of the being terminates with the due performance of the process. And hence the act of Reproduction is maintained by Spencer and others to be habitually and normally opposed to that of nutrition. The conservation of the *individual* being, in this way, antagonistic to the conservation of the *species* or *race*.

Nor can these somewhat unusual phenomena appear strange or inexplicable when we reflect on the ulterior purpose of this important process. Its energies are concentrated not solely on the individual exercising them, but on the production and perpetuation in time of new individuals; a function and duty this latter of the highest import, in the face of constant extermination and death. And therefore we find the whole life and energies of the being, its present and ulterior existence, devoted to the perfect development of those phases in its constitution which have for their aim the extension of the form through space, and its perpetuation through time.

The function of "reproduction" or "generation" we thus understand to be that process in the physiological existence of every individual which provides for the production of new individuals, ordinarily resembling their progenitors; or at anyrate exhibiting, after a series of primary developments, a more or less general likeness to the type from which they are produced. Although we thus find the function itself to be universal in its occurrence throughout living beings, the modes in which it may be effected or performed exhibit a very great degree of variation, both as to means on the one hand, and manner on the other. The various forms of the reproductive process thus admit of division, primarily, into two great groups.

The first mode or form of the process is known as "Sexual reproduction," which may be defined as

that in which the two essential elements, those of the male and those of the female, come in contact with each other; the "germ-cell," "ovum," or "egg" of the female, being brought in contact or relation with the "sperm-cell" or "spermatozöon" of the male. We thus observe that the essential feature in this form of the reproductive process is the union of the two distinct sexual elements. Whether these be furnished by the same individual or not, is a fact of immaterial consequence in the recognition of this merely formal definition. The presence of the distinct elements of "sex" is therefore the great characteristic of "sexual reproduction."

The second primary form of the reproductive process is termed "Asexual" or "Agamic" generation; and this division of the process includes a variety of modes or forms, after, or according to which, the reproductive act may be effected. The distinctive and essential feature of all the various modes of "Asexual" reproduction is simply the negative one, as applied to the "sexual" form of the process. In other words, all the forms of the "asexual" reproductive process agree in the fact that no union of male and female elements takes place in this latter variety of the function; and hence we find that the condition is essentially one of growth and development from one primary "individual." We shall, however, have occasion to observe the occurrence, in certain "individuals" or groups, of both of these primary modes of the reproductive process.

Before proceeding to notice in detail the various forms of the function, we may conveniently call attention to the significance of the term "individual," used in a zoological or physiological sense. The zoological "individual" is generally defined as being invariably "equal to the total result of the development of a single ovum;" or, as "the sum of all the successive stages of development, through which the product of a single fecundated ovum passes, whether these stages have an independent existence or not." The essential of each definition lies in the fact that whatever arises or is developed from a single

egg is to be regarded as the zoological "individual;" or conversely, that the result of such development, whatever its form or relations, constitutes a single and "individual" form. Thus in the higher forms of animal life the single "individual" alone, is repeated in the course of reproduction and development. Each ovum or egg, in other words, gives rise to one and a single form known zoologically as an "individual." But we have already had occasion to notice certain organisms (such as the Sea-mat, Fig. 6, or the Hydroid Zoophytes, Fig. 4), which are of compound nature, and which, accordingly, consist of an aggregation or united colony of forms. Are such forms "individuals?" and if not, what relation do they bear to the form so designated? Bearing in mind the essential feature in the definition of the term given above, we may trace the development of such forms, with the result of proving that in most cases the compound organism of the Sea-mat, or *Hydrozoön*, has sprung by a process of budding from a single "ovum" or "egg," or from the primitive being which resulted from the direct development of an "ovum." Hence the entire compound organism must, consistently with our definition, be termed the "individual;" and to each of the separate little beings of which this compound "individual" is composed, the term "zoöid" is applied. The true "individual," in short, is the product, directly or indirectly, of the "sexual" or true reproductive act; whilst the "zoöid" is the product of "asexual" modes of generation. Lastly, it is to be remembered that, firstly, "zoöids" may be perfectly free and independent of the organism from which they are produced; their *mode of origin* being therefore the sole criterion of their true nature. And secondly, the "zoöid" itself may give rise, through a true sexual process, to "individuals," which are truly such, in virtue of the fact that they exemplify each the "total result of the development of a single ovum." Bearing these broad generalisations in mind, we shall be the better able to fully appreciate the various phenomena in which "individuals" and "zoöids" respectively take part.

Turning our attention to the "sexual" mode of reproduction in the first instance, as exemplifying the process in its most usual and highest form, we observe this variety of the function in greatest perfection among the higher animals. We are generally aware, from external peculiarities of form in the higher animals, of the distinction of the "sexes." The peculiarity and essential feature in the nature of "sex," being the power of producing one of two distinctive elements necessary for the due performance of the reproductive process. We thus know that the "male sex" is characterised by the power of producing "spermatozoa;" whilst the function of the "female sex" is devoted to the production of "ova," or "eggs." The "sexes" in the higher forms are accordingly found situated in different individuals, known respectively as "males" and "females;" but in many forms, of even high rank in the scale of creation, we find the two sexes to be contained within one and the same individual. Where the sexes are distinct, and situated in different individuals, we term such forms "diœcious;" and where male and female organs of reproduction are contained within one and the same form, the individual is said to be "monœcious," "hermaphrodite," or "androgynous." In "monœcious" forms, however, although the power of producing ova and spermatozoa resides in *one* individual, we often observe that the sexual union of *two* such "hermaphrodite" individuals appears necessary for the due impregnation of the ova. The opposite sexes in each "monœcious" form being brought into contact in this way.

The essential feature in the "sexual" form of reproduction, therefore, consists in the contact of the "spermatozoa" of the male with the "ova" of the female. A consideration of the modes in which this process is effected throughout the animal series belongs to the province of the systematic naturalist; whilst the tracing of the subsequent development of the ovum through its various stages to the final appearance of the perfect form, falls to be more appropriately considered when treating of "Development" at large.

The essential organs of the "male" consist of "spermaria," or receptacles in which the "spermatozoa" are formed and developed. These "spermatozoa" or spermatozoöids consist of variously-shaped, hair-like, or filamentary bodies (Fig. 21, A), usually of very minute size,

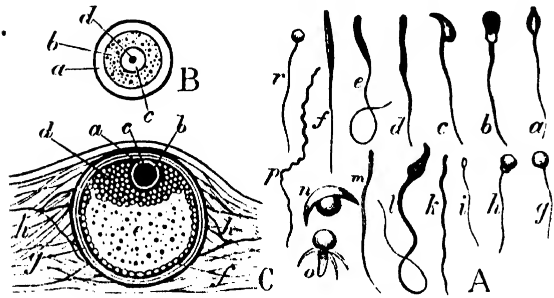

Fig. 21. Ova and Spermatozoa.

A, Spermatozoöids of various animals: *a*, Man; *b*, Squirrel; *c*, Rat; *d*, Cock; *e*, Lizard; *f*, Frog; *g*, Perch; *h*, *Cobitis* (Fish); *i*, Limpet; *k*, Sea-Lemon (Mollusc); *l*, Snail; *m*, Insect; *n*, Crab; *o*, Hermit Crab; *p*, Earthworm; *r*, Sea-cucumber. B, Diagrammatic section of an ovum: *a*, "vitelline membrane" or "zona pellucida;" *b*, yolk or "vitellus;" *c*, "germinal vesicle;" *d*, "germinal spot." C, Semi-diagrammatic section of *Mammalian* ovum *in situ*, surrounded by its coverings and "ovisac:" *a*, "zona pellucida;" *b*, vitellus; *c*, germ-vesicle and germinal spot; *d*, "discus proligerus," or layer of cells investing the ovum; *e*, cavity of "Graafian vesicle" or "ovisac," usually containing fluid; *f*, "membrana granulosa" or "granular membrane," lining the walls (*g*) of the ovisac; *h*, "stroma," or tissue of the "ovarium" or ovary, in which the "ovisacs" or "Graafian vesicles" lie imbedded.

and generally possessing a more or less rounded "head," to which is attached a vibratile "tail." Under the microscope these bodies are seen to exhibit active movements, resembling those of animalcular forms, and from this resemblance the common name of "seminal animalcules" has been applied to the "spermatozoöids." The nature or source of such movements is completely unknown to us. The "spermatozoöids" appear to be developed within characteristic cells of the "spermaria,"

to which the names of "sperm-cells" or "vesicles of evolution" have been applied.

The analogous organs of the female economy are termed "ovaria;" their characteristic productions being known as "ova" or "eggs." The "ovaries" or "ovaria," in the higher animals at least, are composed of loose tissue or "stroma" (Fig. 21, C *h*); the "ova" being produced within sacs or capsules imbedded in this "stroma," and termed "ovisacs" (*g*), or in the mammalia, "Graäfian vesicles," after De Graäf, their discoverer. The term "ovisac" is, however, of more general application, and therefore to be preferred. The "ova" are generally of minute or microscopic size, and exhibit each the characters of a typical nucleated cell. The "cell-wall" of the ovum is known as the "zona pellucida" or "vitelline membrane" (Fig. 21, B *a*). The "nucleus" of the cell corresponds to the "germinal vesicle" (*c*). The "nucleolus" or inner nucleus is represented by the "germinal spot" (*d*); whilst the cell-contents are represented by the "vitellus" or "yolk" (*b*). These three parts are found present in greater or less detail in all ova; and the structure thus described is essentially that of the ovum of all animals prior to impregnation. In the higher animals the relations of the ovum to its coverings are better seen than in the lower forms; and it is in the arrangement and relative position of these coverings, that the essential difference between the ova of the various classes of the *Vertebrata* especially consists. In the lower forms, the "ovisac" is generally closely applied to the "ovum," thus leaving little or no interval between them; but in the *Mammalia*, in which the relations of the ovum and its coverings have been principally studied, we find several cellular structures interposed. As seen in the diagrammatic section of the Mammalian ovum in Fig. 21, C, the walls (*g*) of the ovisac are represented; and situated within the inner wall, so as to form an inner lining to the ovisac, we find the layer of nucleated cells known as the "membrana granulosa" (*f*). This same cellular layer also closely invests the

ovum itself, and forms an ovular covering, known as the "discus proligerus," or "granular zone" (*d*); whilst within this "discus proligerus" lies the ovum itself, constituted by the "vitelline membrane" (*a*), the "vitellus" or "yolk" (*b*), the "germinal vesicle," and "germinal spot" (*c*). These four last-mentioned parts, as already remarked, are common to the ova of all animal forms.

The term "impregnation" or "fecundation," is applied to the process by which the "spermatozoöids" are brought in contact with the "ova," and as a result of this contact the "ova" are accordingly said to be "impregnated" or "fecundated;" that is, the essential conditions for the production of a new being have been fulfilled. The exact nature of the contact between the male and female elements is not known. In what the essential principle or *materies* necessary for fecundation consists we do not know; and the reason or cause why the "spermatozoöids" should possess in themselves so peculiar a power, is a matter regarding which we can only speculate and theorise. In most cases, it would appear that the "spermatozoöids" enter the ovum, and come in contact with the "yolk" and "germinal vesicle;" this contact being provided for, sometimes by the rupture of the envelopes of the ovum, or in other cases, by the existence in the ovum of a special aperture.

The consequent changes which it is the province of Development to chronicle, are thus induced; and as a final observation, we may remark, that the act of "impregnation" is thus dependent upon the "fusion," as it were, of the properties of the male and female elements. We can safely assert thus much, although, as above stated, the exact nature of these properties, or of the fecundative process, is wholly unknown. It may only be further noticed in the present instance, that whilst in the higher forms of animal life the process of impregnation is generally effected within the body of the female, in the lower forms impregnation usually takes place external to the body. And similarly with the subsequent development of the fecundated ovum; this latter process, in the higher

forms, taking place within the body of the parent-organism, and in the lower forms, being generally, though not universally, carried on without the body, and often independently of parental care.

The consideration of the "asexual" processes of reproduction leads us to notice very different phases from those observed in the "sexual" method. We now approach to the observation of modes of reproduction, which simulate, in a manner equally strange and wonderful, the processes of ordinary "growth" and nutritive addition. The process of "sexual" reproduction, in its earlier stages at least, and viewed analogously, is merely a process of growth: since we have to consider, in a generalised aspect, the "ovaria" and "spermaria" especially of lower forms, as simply specialised "buds" or processes of the body-surface, subject to the same laws of growth and formation as the other parts of the organism. But the various modes of "asexual" reproduction exemplify this latter observation in a far greater degree than the most generalised view of the "sexual" form of the process. As we shall presently observe, several modes of "agamic" reproduction mimic, in the most extraordinary manner and in closest detail, the phenomena of vegetable generation and growth.

Two chief forms of the "non-sexual" or "agamic" modes of reproduction await our consideration. The first of these modes is that in which an organism reproduces itself by the production of "buds," springing either from its external or its internal surfaces, and which finally develop into new beings. Such a process is known as that of "Gemmation" or "Budding," and, according to the surface of origin of the buds, the process is termed "external gemmation" or "internal gemmation." This process of "gemmation" is further termed "continuous" or "discontinuous," according as the buds remain continuously and permanently connected to the producing surface or organ; or as they are detached from the parent-organism at an earlier or later stage in their life-history.

The second mode in which the "asexual" repro

ductive process may be effected, is that of "fission," or simple division of the body-substance of an organism; which original material becomes thus simply divided into new beings; and these new beings may either remain attached to and "continuous" with the parent-form, or become free, detached, and "discontinuous" organisms, just as in the case of the "gemmative" or "gemmiparous" products.

In the case of these latter modes of reproduction, we see many illustrations of the "vegetative repetition of similar parts," especially in "continuous gemmation;" but when the produced "gemmæ" or buds separate from or become "discontinuous" with the parent organism, it may be difficult or even impossible to say whether the process of "fission" or "gemmation" has been at work. A comparison of "fission" and "gemmation," will, however, readily bring to light the essential difference between these two modes of reproduction, relatively to the forms produced by either. Thus, in most cases of "fission," the detached portions simply require the ordinary process of "growth" to develop them into organisms, like those from which they were detached. Whilst, in "gemmation," the process is more purely and truly reproductive, in that a more or less defined process of "development" has to be gone through ere the primary form of the bud becomes transformed into a being, resembling that which gave it origin.

The terms "produced" and "producing" zoöid, so frequently occur in considering the "asexual" reproductive processes, that it may be well to explain the meaning of these expressions. Thus, when, as in the case of the Hydra (Fig. 7, 1), we find an organism or "zoöid" giving origin to other "zoöids," which become detached or "discontinuous," we term the first or parent "zoöid," the "producing," and the others the "produced" zoöids. Then, where we have successive series or generations of "zoöids," we term each zoöid of the first series a "protozoöid;" those of the second are "deuterozoöids;" those of the third, "tritozoöids," and so on.

Lastly, it is to be borne in mind that the parent or "producing zoöid" may possess true sexual or reproductive organs, that is ovaria and spermaria; and the "produced zoöids" may also develop generative organs—although it will be understood that both the "produced" and "producing zoöids" may as frequently be destitute of "sexual" reproductive powers, and be able in this latter instance to produce new forms only by a process of gemmation similar to that by which they themselves were produced.

We shall now consider in order the processes of "fission" and "gemmation," together with several phenomena, in which analogous reproductive phases may be said to take part.

"Fission," or simple division of the body-substance of an animal to form new, separate, and generally independent organisms, is seen typically in the case of the *Actinozoa* and Coral-polypes, in *Infusoria*, *Rhizopoda* (such as *Amœba*), and in many other forms. The Coral-polypes and their allies exemplify for us the "continuous" form of "fission." In these organisms we find the polypes frequently dividing spontaneously, and in various ways, but usually by the vertical division of the animal through its mouth, and downwards through its body; the primary form being thus divided or separated into two distinct, yet connected and "continuous" organisms, which may in turn divide in like manner. The common *Actinia* or Sea-Anemone, and allied species, occasionally divide spontaneously, and exhibit a result similar to that seen in their neighbours the Coral-polypes. And the process of "fission" has been also observed in various members of the *Hydrozoa*, of which class the *Hydra* (Fig. 7) is the type.

In *Infusoria* (Figs. 5, 22, 23), we find many and most typical examples of "discontinuous fission," and also of the various modes in which it may be effected. Thus we may, as in *Vorticella* (Fig. 22, B), find it to be longitudinal; the flower-like head (*a*) of this form exhibiting a longitudinal cleavage (*b*), and finally, one half of this

cleft head falling off the stem (*c d*), and thereafter developing a new stalk, and assuming the perfect likeness of the parent-form (*a*). Transverse fission may also occur in *Infusoria*, as in *Stentor*, *Nassula*, etc. (Fig. 23, I); whilst other species (*Paramœcium*, Fig. 23, F, etc.), exemplify either or both of these modes of accomplishing fissiparous reproduction (Fig. 23, G, H, I). The idea that the reproductive organs of these animalcules—that is to say, the "nucleus and nucleolus" (Figs. 22, A, *n*, and 23, F, *a b*),—take part in the process of "fission,"

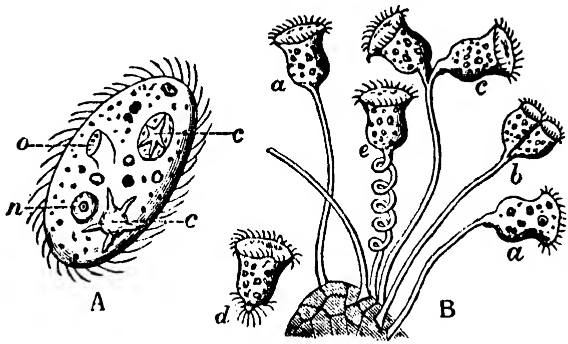

Fig. 22. INFUSORIA.

A, Diagram of *Paramœcium*, a familiar *Infusorian* form: *c c*, contractile vesicles; *n*, nucleus and nucleolus; *o*, mouth and rudimentary gullet. B, Group of *Vorticellæ*; *a a*, adult *Vorticellæ*; *b*, an animalcule beginning to divide fissiparously; c, further stage of *b*, two heads being borne on the one stalk; *d*, detached head, furnished with cilia, and which for a time leads a locomotive existence; e, *Vorticella*, contracted on its stalk.

does not appear to be borne out or confirmed by recent investigations. Since, as remarked by Greene, in some cases the division of the nucleus "into two parts is not effected until that of the body is nearly complete, or it may happen that fissure of the nucleus is not participated in by the body as a whole." The *Rhizopoda* represented by *Amœba* (Figs. 1, and 23, E), also exemplify the fissiparous mode of reproduction; a "pseudopodium" or

finger-like process of the body being, as seen in Fig. 23, E, frequently cast off to assume all the functions of a new being.

The process of "gemmation" or "budding" involves the consideration of more complicated phenomena than those witnessed in the process of "fission." Gemmation may be "external" or "internal;" "continuous" or "discontinuous." The reproduction of lost and injured members, so well exemplified in the case of Crustacea, Star-fishes, etc., appears to be effected by a process analogous to that of budding. But there is no further connection or analogy than this mere identity in kind, to be drawn between this reproduction of lost parts and the reproduction of true organisms or "zoöids." We find many and excellent examples of "gemmation" amongst nearly all classes or groups of *Invertebrate* forms. The *Protozoa* exemplify the process in many interesting examples, and the *Foraminifera* may be held as illustrating the process very completely. These forms (Figs. 2 and 23) consist each of a little mass of "sarcode" or "protoplasm," which possesses the power of building up around its primitive body a similarly minute, calcareous, or limy "shell;" and through holes or "foramina" in this shell the little "pseudopodia" or "false feet," so well seen in the *Amœba* (Fig. 1, *a b*), are protruded. A *Foraminifer* simply consists of an Amœba-body within a perforated calcareous envelope or shell.

The *Foraminifera* are divisible into two great groups, according as the shell is single or many-chambered. And the study of the morphology of *Foraminiferal* forms has shown us that the "Multilocular" or many-chambered shells were originally single-chambered (Fig. 23, A), and were produced each from a single-chambered form by a process of "continuous gemmation;" that is, by the addition of new chambers budded out from the primitive apartment. Thus we have various typical forms developed. If "gemmation" proceed in a straight line, we have the single-chambered shell converted into a multilocular and linear structure (Fig. 23, B). Or if the new segments be successively larger than the older ones,

the shell will tend to become conical in shape (Fig. 23, C). And between all the different chambers of a multilocular shell, whatever its shape or size, there exist apertures of communication, so that the primitive "sarcode" is con-

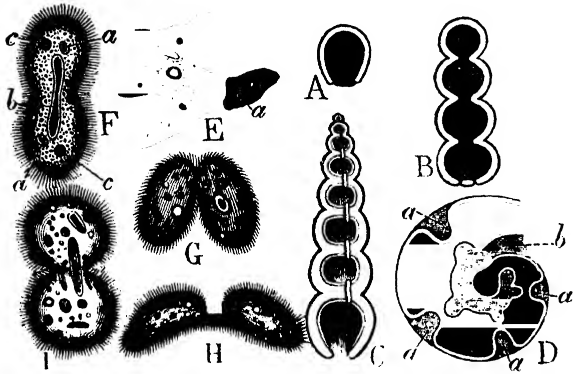

Fig. 23. ILLUSTRATIONS OF FISSION AND GEMMATION.

A, Section of Monothalamous or "single chambered" *Foraminifer*. B, Section of Polythalamous or "many-chambered" *Foraminifer*, showing the production of a linear series of equal chambers by gemmation. C, Section of many-chambered *Foraminifer* (*Marginulina raphanus*), showing the increase in size of the successive chambers, producing by gemmation a spiral or conical shell. D, Helicoid or Snail-like shell of *Foraminifer* (after Huxley), formed by the coiling of the segments or chambers to form a flat, close spire, the coils of which lie in one plane: *a a*, additional material thrown out to fill up the spaces between the septa or partitions; *b b*, material filling up the gaps between the whorls of the shell (*a*, interseptal, and *b*, intergyral spaces). E, *Amœba*, undergoing process of fission: *a*, one of the finger like processes or "pseudopodia" detached to form an independent animalcule. F, *Paramœcium bursaria* (Stein) dividing transversely: *a a*, nucleoli; *b*, nucleus; *c c*, contractile vesicles. G, *Glaucoma scintillans* (Ehrenberg) dividing vertically. H, *Glaucoma* undergoing a second process of fission. I, *Nassula ornata* (Ehrenberg) dividing itself by transverse fission.

tinuous and organically connected throughout the chambers of this curious domicile. Then similarly we can conceive of spiral shells being formed by the spiral arrangement of the budding segments (Fig. 23, D); and

other forms of symmetry may be developed after analogous fashions. The process is thus truly one of "continuous gemmation;" nor do I think that the recognition of the "vegetative repetition of parts" can be so strongly insisted upon here, inasmuch as the repeated parts are not in most cases so thoroughly alike the original segments as is implied by the use of this term. The budded segments are not perhaps to be regarded in the light of distinct zoöids; but in spite of these considerations the process of reproduction known as "continuous gemmation" is exceedingly well exemplified in these forms.

Among the *Cœlenterata* the "continuous" and "discontinuous" forms of gemmation are well exemplified. The *Hydra*, or common Fresh-Water Polype (Fig. 7, 1), in one phase of its reproductive process exemplifies "discontinuous gemmation." During the warmer months of the year we find the *Hydra* to exhibit little bud-like projections on the sides of its body. As development advances, a mouth and tentacles are developed at the free or "distal" extremity of this little bud, and in due course we are presented with a little *Hydra* budding from the sides of its parent (Fig. 7, 1), to which in every respect, save perhaps in size, it bears a close resemblance. The parent *Hydra* in such a case would be termed the "producing," and the young budded organism the "produced" zoöid; for the parent *Hydra* is merely a "zoöid" similar to its "gemmiparous" offspring. If we suppose the parent *Hydra* to have been produced from an ovum, that is by "sexual" reproduction, the parent would, in this latter case, be simply a "zoöid;" since the zoological "individual" would be constituted by the parent Hydra, together with all the "zoöids" which might be produced by "gemmation" from it. The "total result of the development of a single ovum," including not the parent *Hydra* alone, but all the "zoöids" which spring by "gemmation" or otherwise from it. In the *Hydra* the zoöids may remain connected to the parent organism for a period of greater or less duration; but they invariably drop off from the "producing zoöid," and seek a new

and independent existence. The primary buds to which the parent or "producing zoöid" gives origin, may in turn, and whilst still connected to the parent organism, produce by budding a second generation or series of zoöids ; and we may thus have three generations of *Hydræ* connected together for a longer or shorter period, but eventually becoming detached organisms. Such a combination illustrates the terminology applied to the successive series of "zoöids ; the parent zoöid being the "protozoöid," the primary buds the "deuterozoöids," and the secondary series of buds the "tritozoöids."

In other members of the class *Hydrozoa*, exemplified by the Sea-firs and their allies (Fig. 4, *a b c d*), and in the *Mollusca*, represented by the Sea-mats (Fig. 6), we find typical examples of "continuous gemmation," and of the "compound individual" and its component "zoöids" also. In most *Hydrozoa* we find the branching tree-like organism to consist generally of a main stem and branches (Figs. 4 and 24, A), bearing numerous little "zoöids" (*a a*), produced from a primitive being by a process of "gemmation ;" but which, unlike the "zoöids" of the *Hydra*, remain permanently attached together, to form the compound organism we know as the "individual."

The Flustra or Sea-mat (Fig. 6, *a*) exemplifies a similar condition of parts. In this organism we find the little "zoöids" enclosed in tiny cells (Fig. 6, *b*), the aggregation of such "zoöids"—or "polypides," as they are termed in the case of the "Sea-mats"—making up the zoological "individual." Like many of the *Hydrozoal* "individuals," the compound organism of the "Sea mat" springs by "gemmation" from a single primitive "polypide." And in each of the preceding cases every "zoöid" may, roughly speaking, produce true "ova" by "sexual" reproduction, and from these ova the compound "individuals" will in turn be produced.

These examples may be deemed sufficiently illustrative of "external gemmation" in its two chief aspects. We may next, and very briefly, observe the phenomena incidental to the "internal" form of the same process. Such

a process is exemplified typically in the case of forms allied in nature to the "Sea-mats," or *Polyzoa*, as they are collectively designated. These organisms ordinarily reproduce their species by means of true ova, from which by "gemmation" the compound organisms are developed. In connection with these forms, and chiefly by aid of the researches of Professor Allman, a second set of so-called "ova" has been detected; these latter being developed, not in the "ovaria," but by budding from a cord-like structure, the "funiculus," which is attached to the lower and posterior extremity of the stomach. Such "ova" have been termed "winter ova" or "statoblasts." These "statoblasts" are enclosed in a curious envelope of corneous or horny texture, and appear to be contained for a longer or shorter period within the body-cavity of the organism. The "winter ova" are liberated during the colder season of the year—and hence their name—by the death of the organism in which they were produced, or by other means of escape; and from the free "statoblast" there issues in due course "a young *Polyzoön*, already in an advanced stage of development, and in all essential respects resembling the adult individual in whose cell the statoblasts were produced" (Allman). Such a form, when thus liberated from its statoblast, gives rise, by "continuous gemmation," to the "compound individual;" the separate "zoöids" of which will in turn develop these "statoblastic" germs.

At first sight, therefore, this would appear to be a case of "discontinuous gemmation," since we have the "compound individual" giving rise through its "zoöids" to single "individuals," from which, again, the compound form is produced by budding. But Dr. Allman has shown that these "statoblasts" are not to be accounted true ova, from the fact, that an "ovarium" exists in each "zoöid," and produces true ova independently of these "statoblasts;" and also from the fact that these "winter ova" do not exhibit or pass through the characteristic phases which invariably accompany the development of true "ova." Dr. Allman is therefore of opinion that

these peculiar bodies are to be regarded as internal buds or "gemmæ" in a state of encystation, and which thus remain for a certain period in a "quiescent or pupa-like state." The value of such researches in aiding us to draw the very necessary, but not always patent distinctions between (*a*) true ova, (*b*) separated or detached "gemmæ" or "buds," and (*c*) attached buds, cannot be too highly or over-estimated.

Having thus investigated the nature of the typical forms of the reproductive process, we may next in order turn to the consideration of certain more complicated phenomena connected with the successive cycles or reproductive phases through which many forms pass in the course of their reproductive and developmental history. It is needless to remark that the significance and relation of the terms "individual" and "zoöid" must be clearly borne in mind in such investigations; since the explanation of these and allied phenomena amounts simply to the tracing out of these two forms, in which an entire organism may at once, or interruptedly, make its appearance.

Such cycles of the reproductive process may be typically witnessed in the case of most *Hydrozoa*, in certain of the lower *Mollusca*, in the *Tæniadæ* or tape-worms, and in allied forms. The first-mentioned group will exemplify the phenomena we are about to describe in the simplest, and at the same time most typical, manner. With many forms of *Hydrozoa* every seaside visitor will be familiar, and we have already had occasion to notice the general morphology of the group. The illustrations at Figs. 4 and 24 will serve to impress the essential features of a *Hydroid* Zoophyte on the mind; and we thus observe that the organism presents us with a branching tree-like structure (Figs. 4, *a c*, and 24, A) growing from a fixed rooted point, and in every way resembling a vegetable production. If we magnify a portion of such an organism (Figs. 4, *b d*, and 24, B), we find the branches bearing small cells, of varying form and size, in place of leaves or flowers. Each cell contains a tiny inhabitant

or "polypite" as it is technically called (Fig. 24, B, *a*): and with the knowledge that each "polypite" consists of a soft tubular body, terminating superiorly in a mouth and crown of tentacles (*a*), and communicating internally with the general cavity or interior of the branch on which it is borne, we shall possess a sufficiently clear idea of the essential features of each little member of this strange commonwealth. For each "polypite" is exactly the counterpart of all its neighbours, and although, in a manner, every member of the colony is independent of its fellow-beings, it yet contributes its share to the nutrition and support of the colony at large. Through the hollow connecting medium or "cœnosarc" (Fig. 24, A, *c c*), which binds the members of this commonwealth together, a constant circulation of fluid is kept up. And to the current of this nutritive stream each "polypite" contributes its quota of elaborated matter, and in turn derives its nutriment from this common source. The entire organism is therefore nourished by the united efforts of its semi-independent members; just as the leaves of the tree at once contribute to and draw upon the general fund of nutriment, in the formation and elaboration of which they all aid.

A very brief consideration of such an organism will show us its morphological and physiological composition. The entire Zoophyte is simply an "individual" of compound nature; whilst its component members or "polypites" are "zoöids," produced by a process of "continuous gemmation" from a single and primitive embryonic form.

A further and more detailed examination of the zoophyte, however, would reveal the fact that, to all appearance, it could increase and extend its growth simply by the power of "gemmation" by which it was primarily developed As the leaves of the tree fall and wither, so, in a manner, do the little "polypites" of the *Hydrozoön*; but the power of "gemmation" amply suffices for the renewal of these disintegrated portions, and thus new growths of these little buds are continually taking place from the common medium or "cœnosarc," and fresh members are thus added

to the commonwealth to fill the place of those which have died or fallen away.

We have thus ascertained that the "individual" in this case consists of numerous connected "zoöids," which perfectly nourish the organism, and which are produced and renewed by "gemmation."

If we now return to our present comparison of the zoophyte and the tree, we shall at once detect a gap or break in the parallelism. We have provided for the growth and nutrition of the one "individual," but not for the production of *new* "individuals." The zoophyte, as we have seen it, exhibits in its life the simple phenomena of growth, and nothing more—nutritive growth on the one hand, and a reproductive growth by gemmation on the other. But this latter form of the reproductive process is incompetent to perpetuate the species. It is simply sufficient to add to and extend the "individual," just as the leaves, root, stem, and branches, extend the growth of the single tree. The tree, however, possesses true reproductive, as well as merely nutritive organs, and these reproductive organs we know as the flowers. From these flower-buds will in time arise the true sexual elements from which a new being or tree will spring. If the parallelism between the zoophyte and the tree be perfect, we will require to show that the former possesses buds or organs which will correspond in function to the flower-buds of the latter.

In our previous and general examination, therefore, we detected only one set of "zoöids" or buds; but our more minute examination reveals a second set or series (Fig. 4, *d;* and 24, A B, *b b*),—these latter zoöids devoted not to the nutrition but to the reproduction of the organism. Hence, in reality, our miniature commonwealth is composed of two sets of members: the hydroid "individual" is constituted by a double set of zoöids. Collectively we designate all the nutritive zoöids of the "individual" the "trophosome" (Fig. 24, A, *a a*); whilst the reproductive zoöids similarly make up the "gonosome" (Fig. 24, A, *b b*; and B, *b*).

The "individual" so formed is primarily, therefore, of a double nature; the two series of zoöids are essentially

different in form, and different in function also ; although morphologically the two series are constructed on the same

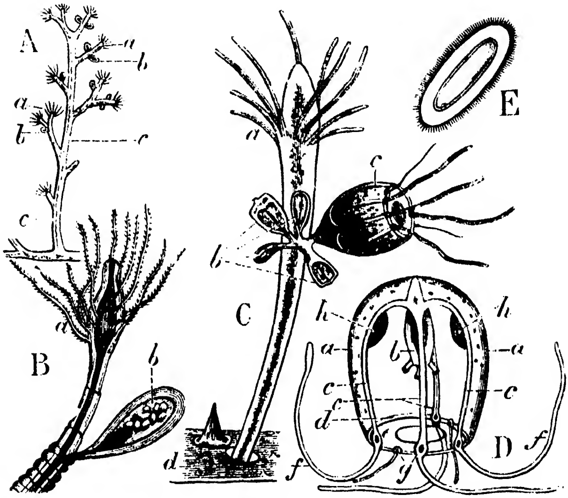

Fig. 24. Reproduction of Hydrozoa.

A, Portion of the "hydrosoma" or entire organism of *Cordylophora lacustris* (Allman), natural size : *a a*, nutritive polypites or zooids ; *bb*, reproductive zooids or "gonophores ;" *cc*, connecting medium or "cœnosarc." B, Branch of *Cordylophora*, greatly magnified, showing a nutritive zoöid or polypite (*a*), and a reproductive zooid or "gonophore" (*b*) containing ova. C, Portion of *Podocoryne carnea*, greatly magnified (after Hincks : *a*, an ordinary "polypite" with tentacles ; *b*, "gonozooids," or reproductive zoöids, in various stages of development ; *c*, a gonozoöid fully developed, and on the point of detaching itself ; *d*, connecting crust or medium of the polypites. D, The free gonozooid or "Medusoid" embryo of *Podocoryne carnea* (C), having detached itself from the plant-like organism ; *a a*, swimming-bell or "umbrella ;" *b*, manubrium ; *c c c*, "radiating" canals terminating in, and connected by, the "circular" canal (*d*) ; *e*, "veil" with central aperture ; *f f*, tentacles ; *g*, ocelli ; *h h*, reproductive organs. E, "Planula," or general form of the "embryo" of *Hydrozoa*.

fundamental plan. Just as the flower and leaf-buds of the tree differ in function, but are morphologically, and so far

as their fundamental type is concerned, the same, so are the nutritive and reproductive "zoöids" of the *Hydrozoön* primarily identical in structure, but, as we observe them, they differ in outward form, and present a wide dissimilarity of function. The nutritive zoöids contribute to the nutrition of the entire organism, including also the reproductive zoöids, whilst these latter provide for the perpetuation of the organism, of which they thus form an important part.

If we now trace the further life-history of the zoophyte, we shall find a curious sequence of phenomena brought under our notice. We have seen the nutritive phase of its existence, and we next observe its reproductive cycle. In some cases we find that the "gonozoöids" or "gonophores," as the reproductive buds are called, may remain permanently attached to the organism (Figs. 4, *d*; and 24, A, B), and discharge their contents—"ova" and "spermatozoöids"—into the surrounding water; or more typically, and as in the case before us (Fig. 24, C, *b c*), the "gonozoöids" may remain comparatively undeveloped whilst attached to the parent organism, and, only after detaching and separating themselves from it, do they mature the reproductive elements which it is their function to elaborate and develop.

We thus find that, in the latter case, the "gonozoöid," (Fig. 24, C *b*), having attained a certain development, liberates itself (*c*) from the "ectotheca" or envelope in which it is contained whilst attached to the parent organism, and floats freely away in the surrounding water, thus entering upon a completely new phase of existence. We now find the free and independent gonozoöid (Fig. 24, D), exhibiting a form singularly unlike that of the being which gave it birth. Nor can we feel surprised, as we contemplate this beauteous form, that the older naturalists should imagine it to be an organism *specifically* distinct from the zoophyte, and that they assigned to it the rank and place of a true "individual." We now behold a delicate fragile form, consisting of a bell-shaped body, (Fig. 24, D, *a*), composed of a clear crystalline jelly, which

is tinted, as it moves gracefully through the water, with all the most beautiful of cerulean hues: a clear crystalline dome, swimming through the sea by the alternate expansion and contraction of its bell-shaped body, or "umbrella" (*a*), as it is technically called. And such a form, in all its many varieties, will be familiar to every seaside visitor as the *Medusa*, "jelly-fish," or "sea-blubber"—a being popularly accounted of distinct "individual" identity, and as unlike the form from which it was derived as we could conceive any form to be.

This "medusoid" form, or free "gonozoöid"—for we must not, in spite of its altered form, lose sight or recollection of its original relation with the zoophyte—possesses a structure also peculiar to itself. If we compare its body to a bell, we find a hollow central organ, known as the "manubrium," depending, like the "clapper" from the roof of the bell, into its interior (*b*). At the free extremity of the "manubrium" we find a mouth, whilst from its attached or upper end we observe a series of tubes or canals (*c c c*) to radiate from this central point to the edges of the bell or "umbrella," where they open into a "circular vessel" (*d*) which runs round the margin of the disc, and thus connects the "radiating canals" together. The "manubrium" is simply a modified "polypite" or nutritive "zoöid," and the radiating system of canals subserves the function of a digestive or circulatory system, to distribute throughout this strange economy the products of the digestive or nutritive function.

The margin of the "bell" is provided with a variable number of tentacles (*f f*), at the bases of which, peculiar little bodies of the nature of pigment-cells (*g*), with brightly coloured and contained particles, are situated. And along the margin, and between the insertions of the tentacles, we also find a number of small saccular organs, containing little calcareous or mineral particles, suspended in a clear fluid. To the former bodies, the function of sight has been assigned, whilst the latter are generally believed to be auditory or hearing organs; but there appear to be reasonable grounds for doubting the correct-

ness of these ideas. Then, finally, we observe the open mouth of the bell below to be more or less completely closed by a delicate membrane termed the "veil" (*e*); this membrane possessing a central aperture of variable size.

So far the "medusoid" zoöid provides for its nutrition, and its further and still more characteristic development is marked by the appearance of the reproductive organs (*h*). These latter organs are developed at various stages of its existence; this free *Medusa* in some cases possessing a generative apparatus before its detachment from the zoophyte, and in other cases producing them only after a lengthened period has passed in its free state of existence. But generally, and in either case, with the maturity of the generative organs, the nutritive energies of the "gonozoöid" seem to disappear; and its existence usually terminates with the full development of its reproductive system, and with the fulfilment of its peculiar and characteristic function.

And a no less curious series of phenomena than those we have just traced, may yet be perceived in the latter history of the *Medusa*. The true reproductive organs destined for the exercise of the "sexual" form of the process are developed between the walls of the "manubrium," or in special sac-like structures (*h h*) situated on the radiating canals. They consist either of the typical "ovaria" or of "spermaria," destined for, and capable of, reproducing a new being by true "sexual" generation. But in addition to these reproductive organs destined for the performance of the sexual process, we find that the "gonozoöid" may apparently emulate the "gemmative" or "budding" tendencies of its progenitor; and, accordingly, we may observe it to produce "medusoid buds," which resemble their parent in every particular, and which soon detach themselves from the parent form, and propel themselves in like manner through the water. And thus we may find that these secondary *Medusæ* will also develop true reproductive organs, and repeat the same cycle of existence through which their parent is destined to pass.

Finally, however, the process of sexual reproduction takes place in our Medusa's history, that process consisting in the escape from the parent body of the ripe "ova" or "spermatozoöids," and in the subsequent impregnation and fecundation of the ova. The free "gonozoöid" or *Medusa* may then disintegrate and pass out of existence, or it may die before the ova escape; these developed germs being liberated by the death of the organism, and being subsequently fertilised. Or, lastly, we may find the "gonozoöid" to undergo a "retrograde development" or "metamorphosis" after the escape of the reproductive elements, in the course of which it loses its clear crystalline appearance and characteristic form, shrivels up, and then dissolves away, and becomes one with the water in which it so buoyantly swam, and to which, in the delicacy and transparency of its guise, it bore so close a resemblance.

The ova, liberated by the decay of the "gonozoöid," and subsequently fertilised, pass, firstly, through the primary stages of development common to all ova, and then appear in the characteristic form of the *Hydroid* embryo—namely, as a ciliated, elongated, or ovoid body, known as the "planula" (Fig. 24, E). This embryo, at first free-swimming and independent, at last fixes itself to some marine object, and from this simple form a primitive "polypite" is developed, which gives rise by subsequent and rapid "gemmation" to the branched tree-like zoophyte with which the cycle began. This latter form will, in turn, produce its "zoöids," nutritive and reproductive; the latter destined again to repeat the curious cycle through which their indirect progenitors have passed.

Tracing in order these various stages, for the sake of impressing them clearly on the mind, we find—

(1.) The zoophytic "individual," with its nutritive zoöids (trophosome), and its reproductive zoöids (gonosome), giving rise by the functional development of its "gonosome" to

(2.) The free "gonozoöid" or *Medusa*, which may

produce other free "gonozoöids" by "gemmation," but which ultimately develops "ova" and "spermaria," through which impregnated ova are produced; and these "ova" in turn develop into

(3.) The "embryo" or "planula," which finally gives rise by "gemmation" to the (1) zoophyte or doubly-compound "individual" with which the series began.

How could we reconcile, at this further stage, the parallelism between the tree and the *Hydrozoon?* If we could suppose that the tree detached its flower-buds, which should in turn produce winged seeds, and that these latter should finally give origin to new trees, we should construct a case analogous to that of the zoophyte and its reproduction. The detached flower-bud would correspond to the locomotive "gonozoöid," and the winged seed would be the analogue of the embryonic "planula."

We need not trace any further examples of the same kind, since they would all exhibit the same order of phenomena, slightly varied in the form or mode of exhibition. Our next consideration must be that of investigating the relations of the various forms we have seen to take part in the cycle of reproduction.

The older naturalists, as already remarked, explained the above series of reproductive stages, by assigning to the zoophyte on the one hand, and to the free *Medusa* or "gonozoöid" on the other, the rank and position of true "individuals." And they further supposed that these "individuals" were capable of mutually reproducing each other; that is, that the one generation, resulting from this mutual reproduction, "alternated" with the other generation. Or, in other words, that each "individual" became alternately the parent and progeny of the other. Thus the zoophyte might, firstly, be the progenitor of the *Medusa;* then the *Medusa* became the progenitor of the zoophyte: the offspring of each individual, to use the simile of Chamisso, 'resembled not the parent but the grandparent.' To this series of phenomena, Steenstrup gave the name of "alternation of generations," and he thus expresses himself regarding the chief ideas involved in the term:—

"The fundamental idea expressed by the words 'alternation of generations' is the remarkable and till now inexplicable phenomenon of an animal producing an offspring which at no time resembles its parent; but which, on the other hand, itself brings forth a progeny which returns in its form and nature to the parent animal, so that the maternal animal does not meet with its resemblance in its own brood, but in its descendants of the second, third, or fourth degree of generation."

With extended observation and improved means of research, resulting in the more correct appreciation of the terms "individual" and "zoöid," we now have reason to altogether dispute and deny the correctness of Steenstrup's term, and of the ideas on which it is founded. There is but *one* "individual" concerned in the process, and the alternation is not one of "generations," but one of true "sexual" reproduction with "fission" and "gemmation." The "individual" resulting from the "total development of a single ovum," is embodied in the zoophyte with its double series of zoöids; whilst "gemmation" and "fission" respectively alternate with the process of sexual reproduction in the production by budding, firstly, of the tree-like zoophyte, and secondly, in the detachment by fission from this latter of the medusoid embryo or "gonozoöid." This process of alternation might be more clearly perceived if we supposed that the "gonozoöid" gave origin to its ova without leaving the parent organism. In such a case (exemplified by certain *Hydrozoa*), the alternation would take place without the separation of the reproductive element as a *Medusa;* and thus we would have the zoophytic "individual" giving origin directly to impregnated ova, from which the "individual" would again directly be reproduced.

The primary or "proto-zoöids" in this case are represented in the "gonosome" and "trophosome" of the zoophytic "individual;" the "deuterozoöids" would be constituted by the *Medusæ* or free "gonozoöids; whilst if this latter form gave origin to the Medusoid buds which we have seen it capable of producing, these last would represent the "tritozoöids."

We thus see that the former significance of the term "alternation of generations" is completely altered in the face of these considerations. The entire series of alternating phenomena merely constitute the single and highly-individualised reproductive phase of one individual, and are not, in any sense, the alternations of one generation, or of one individual, with another generation, or with another distinct and specific form. The reproductive phase especially, and the nutritive phase also, are highly-specialised in such cases; and the zoological "individual" may thus be exceedingly difficult of detection or recognition when the already complicated series of phenomena is still further and more highly specialised. We might thus, without fear of contradiction, talk of "alternation of zoöids," but not of "generations;" and the term "metagenesis" has been employed in lieu of Steenstrup's name, as expressing a more correct idea of the nature of the included phenomena.

Closely allied to the previous subject is that known as "Parthenogenesis." By this term we express the occurrence of a curious set of phenomena, typically witnessed in the case of certain insects, and which consist in the production, from the "ova" of an *unimpregnated* or "virgin" female, of new beings or individuals—the ova in such a case undergoing development into new beings, without the act and co-operation of the male element. We have already seen that the true and essential part of "sexual" reproduction is the union or contact of the male and female elements; and a series of phenomena, like the present, when first brought to light, excited, as might readily be supposed, no small amount of surprise and speculation. By Professor Owen, however—to whom we are indebted for this term—the process of "parthenogenesis" is made to include the phenomena of "gemmation" and "fission;" in which, from a "virgin," or, at any rate, an unimpregnated individual, such as the zoophyte, a new series of beings or "zoöids," is produced by "budding," or by "fission," and certain of these "zoöids" generally develop true "sexual" elements. So that, widely applied, the term may even

include the process of "metagenesis" or "alternation of generations." But it is at once more convenient and correct to restrict the name "parthenogenesis" to the development from the "ova" of a "virgin" or unimpregnated female of new beings or "individuals," which ova thus develop themselves, without contact with the "spermatozoöids" of a male.

Professor Owen's explanation of the phenomena of true "parthenogenesis," viewed in this latter sense, rests on the supposition that the original "spermatic force," or essential male elements, are transmitted from generation to generation, and that this store of spermatic elements suffices to impregnate the ova without fresh contact with a male. Or, to use Owen's own words, so much spermatic force is "inherited by the retained germ-cells from the parent-cell or germ-vesicle as suffices to set on foot and maintain the same series of formative actions as those which constituted the individual containing them." And consistently with this continued expenditure of the accumulated sperm-cells, "every successive generation, or series of spontaneous fissions, of the primary impregnated germ-cell, must weaken the spermatic force transmitted to such successive generations of cells."

Remembering the essential and invariable facts that "sperm-cells" must originate from "spermaria," and "ova" from "ovaria," and that both "ova" and "spermatozoöids" must exhibit certain defined and constant characters, and pass through a series of defined changes or developmental stages, we are prepared to investigate these phenomena with some certainty of arriving at a correct idea of the process in virtue of which they originate.

The researches of Von Siebold on the reproduction of Bees, and of Bonnet on that of the *Aphides* or Plant-lice, have laid before us a vast store of facts relative to the details of the "parthenogenetic" process.

The *Aphides* or Plant-lice, which occur in such numbers on all our ordinary plants, produce, in the autumn season, true impregnated ova, the result of the sexual contact of ordinary male and female *Aphides*. These impregnated

ova are generally deposited in the axils of the leaves or branches of plants, and lie without change or development throughout the winter season. In the following spring, however, these ova are developed, and then the curious fact "is observed, that the resulting progeny does not include a single *male*, but consists of wingless *females*, sexless beings or "neuters." These "females" produce young larvæ without sexual congress with a male; and this second generation will in like manner, and without impregnation, produce similar beings. And this succession of generations of these "fruitful virgins," as they are called, may be traced through nine (Bonnet) and even eleven (Duvau) generations, without the birth, presence, or influence of a male individual. Kyber is said to have observed the active exhibition of this process of generation through a period extending over four years, without demonstrating the presence of a single male.

Towards the succeeding autumn, however, winged male individuals once more make their appearance in the last brood of these "fruitful virgins;" and these copulate with their female neighbours, and so produce the fecundated eggs, from which, in the succeeding spring, a new generation of females will be developed to repeat the curious phenomena we have just traced.

In Bees, also, we find an analogous series of phases. Thus the "hive" is composed of three sets of individuals: the "queen-bee;" "drones," or male bees; and "neuters," or "workers," which latter are merely undeveloped or sterile females. The reproductive life of the "hive" commences by the "queen" taking her "nuptial flight" into the air, in the course of which she is impregnated by the "drones" or "males." The "seminal fluid" or male element is received into a special sac or "receptacle," which communicates with the "oviduct," or duct of the ovarium. This communication, however, between the ovarium and seminal receptacle, is under the control of the queen-bee, and can be opened or shut at will.

The cells in the "hive" having, by the indefatigable labours of the workers, been prepared, the "queen" begins to deposit the eggs. And in the process of egg-deposition

the characteristic kind of individual which is to result from the development of each egg is regulated by the contact or non-contact with the male fluid from the receptacle, to which each egg is subjected as it passes from the "ovarium," and along the oviduct, to be deposited in its cell. Thus those eggs, from which "queens" or fertile females and workers are to be developed, are subjected to contact with the male fluid from the receptacle; whilst those ova which are destined to give birth to "drones" or males, are allowed to be deposited without contact with the male element. This latter fact has been verified by Dzierzon, who found, that by permanently cutting off the communication between the seminal receptacle and oviduct, none but males or drones were produced. The queen bee is in all probability guided in this curious and wonderful process by the shape or size of the individual cells, in each of which an egg is to be deposited; the three kinds of cells—workers, drones, and royal or female cells—being of different sizes and shapes.

The subsequent sex or kind of individual which is to result from the development of any given egg, is stated by some observers to be also dependent on the kind of food or nutriment upon which the "larvæ" are fed. The "ova" and larvæ, in this view, are of no sex, and the supposition takes origin from the fact that different larvæ are fed with different kinds of food. "Royal food," in this way, consists of a special "paste;" whilst the ordinary food is simply composed of honey and the pollen of plants. Leuckart, for example, ascertained that the effect of a worker being fed upon "royal food," is to transform it, by the development of its reproductive organs, into a "queen" or "fertile female;" and Landois has also proved that an insufficient amount of food will produce a male, whilst plenty of nutriment will produce a female.

After the due development of the eggs, deposited, as we have seen, by the "queen bee," the population of the hive becomes so considerably augmented, that a portion of the community leaves the parental home as a "swarm;" the old queen heading the exodus from her

former dominions. Another swarm, led by a daughter of the old queen, leaves in a short time after the first; this second queen being impregnated in her flight through the air as in the case of the mother-queen. In this way, and by a similar process of reproduction and development, the reproductive interests of the bee-community are duly provided for.

From such facts as these, therefore, the theory of pure "parthenogenesis" has been formed. What explanation can be given of the theory, or of the facts upon which it is based? If we can consider the ova produced by the "fruitful virgins" of the *Aphides* to be truly such, then the process of pure "parthenogenesis" is exemplified; that is, virgin or unimpregnated females produce ova capable of giving rise to new beings without the presence of or contact with the male fluid. And Professor Owen's view, firstly, that the original stock of "spermatic force" derived from the male *Aphides* in the autumn is transmitted from parent to offspring through many generations; and secondly, that it suffices to impregnate the ova of the descendants of those forms in which the spermatic fluid was originally deposited, seems to account for the facts as they stand. In this view, therefore, we may either assume the existence of objective germ-cells —the transmission of the absolute male elements from female to female; or, on the other hand, we may maintain the transmission of an abstract or subjective spermatic force or principle, which may suffice for the impregnation of the ova. Considering that we do not know the essential principle of the seminal or spermatic fluid, and that we cannot argue against the existence of a subjective or abstract principle which may be transmitted from the objective and real elements, the theory of pure "parthenogenesis" on this ground has somewhat of a definite nature; although, at the same time, such a theory merely fits the facts as they stand, and leaves the exact nature of the phenomena still a matter of doubt.

But other authorities have denied that the ova produced by the virgin *Aphides* are true ova; and they have accord-

ingly been termed "pseudova" or "false ova," and have been regarded as internal "gemmæ" or "buds," the "pseudovum" uniting in some way or other the properties of an ovum and a bud. The process of "parthenogenesis" in this view, therefore, includes the "gemmative" process also; but the explanation so afforded does not coincide so perfectly with the facts of the case as the previous theory. The ideas implied in this latter process accord in some measure with the phenomena of "alternation of generations" or "metagenesis." The sexual insects, which give origin to the "virgin females," may thus be regarded as corresponding to the gonozoöid of the zoophyte with its asexual zoöids; whilst the ultimate origin from the virgin females of truly sexual forms will correspond to the production of the sexual gonozoöid—this latter once more giving origin to the asexual zoophytic-stock. The successive series of "virgin females," in this view, are produced by internal budding, just as the "gonozoöids" are produced by external gemmation and fission from the zoophyte, and as the sexual organs are in turn produced by internal gemmation from the "medusoid form."

Latterly these "virgin females" have been supposed to be hermaphrodite forms (Balbiani); that is, they are believed to be individually provided with male and female reproductive organs. If this view be correct—and further research seems necessary to confirm it—the whole subject is much simplified in its ordinary details; but the adoption or confirmation of this latter view leaves us to account for the regularly normal and periodical production of hermaphrodite offspring from "diœcious" parents, and in turn of diœcious progeny from "monœcious" parents.

In the case of the bees, the "drones" may be considered as having been produced "parthenogenetically" from the queen bee; since we have seen that the eggs from which drones are developed are invariably allowed to escape from the mother without being subjected to the influence of the male element. But the influence of food and situation may in other respects be more or less strongly determi-

native of sex, and of the corresponding development or retardation of the reproductive system. The queen bee, viewed after the modification of Steenstrup's theory, might be considered as possessed of the power both of true sexual and gemmiparous reproduction. Her ova may be considered as "buds," capable of development to form either asexual or imperfectly sexual beings, or to produce truly sexual individuals ; these latter in turn again aiding to produce the characteristics of the being from which they were evolved.

Finally, some authorities have sought to point out and found a constant reproductive law, based on the fact remarked in the opening of the chapter, that the processes of nutrition and reproduction are antagonistic or opposed to each other. This law maintains 'that asexual modes of reproduction are merely forms of growth, and that the process, like that of typical nutrition, is an exhaustive process, culminating invariably in the production of the true sexual elements, by means of which latter the new individual is produced.' This law, applying chiefly to the lower forms of life, is simply a generalisation of the reproductive and nutritive cycles in the lower organisms. The growth of the zoophyte, for example, is rapid and continuous ; active gemmation suffices for the constant repair of lost parts, and for the addition of new zoöids. Nutrition is performed in an equally active, and in every way admirable manner, by the countless tentacles and mouths of the "polypites," and by the incessant circulation through the connecting cœnosarc. But the nutritive cycle is not continuously perfect. It is broken in upon, and interrupted by the reproductive phase ; and when the true sexual elements are produced, the vitality of the organism becomes as a rule impaired. Its functions in the world of being have been duly performed, and its life passes onwards through the rapidly succeeding stages of decline, and of ultimate extermination or death. So marvellously bound up together, and so harmoniously dependent upon each other, are these two chief functions of the living organism.

CHAPTER XII.

Development—Relations of Reproduction and Development—Structure of the Ovum in relation to its Development — Primary Stage of the Developmental Process—Formation of the Blastoderm—Community of First Stage of Development—Von Baer's Law of Development—Second Stage of Special Development—Varieties of Ova—Development as seen in the various Sub-kingdoms—Nature of the Process in *Protozoa*—Third Stage of Development—"Nutritive Development"—Metamorphosis—"Retrograde" Development and Metamorphosis.

We have already noticed, in considering the subject of reproduction, the earlier or preparatory phases and actions which mark the production of a new individual or being. We have thus been led to notice that, throughout the animal series, the conditions under which the true sexual process of reproduction is effected, are primarily and essentially the same. These conditions are the contact of the "ovum" of the female with the "spermatozoids" of the male, and the subsequent and successful fertilisation of the germ, from which the future being is evolved. The process by which this evolution is accomplished is investigated under our present subject, that of *Development*, which thus may be said to chronicle the progress of those after-changes in the ovum that take their origin from the successful performance of the reproductive act.

And throughout the wide domain of physiological science there exists no subject of greater interest and importance than the present; involving as it does the tracing of the primitive germ after its fecundation through the various stages by which it gradually advances from the faint exhibition of vitality to the full maturity of adult and independent existence.

Our present aim will be most satisfactorily attained if

we direct our attention to the phenomena of development in the highest animal forms, and thereafter extend our knowledge in a brief generalisation of the process of development throughout the leading or primary groups of the animal series; noticing, also, the various views which from time to time, and at various periods in scientific history, have been entertained respecting the chief points in the developmental process.

The structure of the ovum, and the disposition of its coverings, have been already described; but the essential points included in this description are worthy of being recapitulated in the present instance. Prior to impregnation, and as it lies in the "ovarium" or "ovary," we find the ovum (Fig. 21, C) surrounded by the coverings derived from the "ovisac" or vesicle in which it is developed and contained. Primarily, the ovum consists simply of the "germinal vesicle" and "germinal spot" (Fig. 21, B, *c d*). But gradually, and as development proceeds, we find the substance of the "yolk" or "vitellus" (*b*) to be formed around the primitive germinal centre; and then, finally, the "zona pellucida," or "vitellary membrane" (*a*), a nearly structureless membrane surrounding and enclosing the other and more important parts of the ovum, is developed, and the essential parts and structure of the egg are thus completed.

It is, however, to be borne in mind, that the structure thus described, is characteristic only of the "ovarian" ovum; that is, of the ovum as it lies in the ovary, and before any changes consequent upon impregnation take place. The parts thus enumerated, as already remarked in treating of reproduction, are common to the ova of all animal forms. Of these essential and common parts, however, the germinal vesicle and germ-spot are those which constitute the most important structures of the ovum, and which consequently are the seat of the important changes induced by the occurrence and progress of the developmental process.

To these primary and essential parts there are gener-

ally added, in the course of purely "ovarian" development, various structures, partaking of the nature of coverings or envelopes to the ovum. The nature, number, and disposition of these coverings vary greatly throughout the animal series; indeed, the differences between the ova of different forms may be regarded as depending almost entirely upon the varied nature of the ovular envelopes. Thus we find the ovum of *Mammalia* embedded in its "Graäfian vesicle" or "ovisac," which is bounded externally by an outer and inner tunic (Fig. 21, C, *g*); whilst closely applied to the inner tunic we find a layer of cellular matter known as the "granular membrane" (*f*), which near the ovum becomes developed to form a cellular investment to it, known as the "discus proligerus" or "granular zone" (*d*). And finally, imbedded within this latter structure, we find the ovum (*a*) itself, occupying a position generally near the external surface or "periphery" of the ovisac. The ovisac, in common with a number of similar and neighbouring vesicles, is embedded in the general tissue or "stroma" (*h*) of the ovarium.

In birds, we observe an illustration of the changes in the structure of an ovum, which a variation in the disposition of its envelopes or coverings may induce. The "yolk" of the Bird's ovum is of large size when compared with the "vitellus" of the Mammal; and the "vitellary membrane" is closely applied to the tunics of the "ovisac," no intervening "granular membrane" or "discus proligerus" being found in the ovarian ovum of the Bird. The characteristic coverings of the ovum in this latter case are formed and added to it in its descent through the oviduct. These coverings in the ovum of the Bird consist of the "albumen" or "white" of the egg; of the shell; and of the membranes pertaining to this latter structure. In their simplest form these latter parts constitute the "chorion" of the egg.

In size ova vary greatly; those of the highest animals being exceedingly minute; whilst in Reptiles, Birds, Fishes, and in many *Invertebrata*, we find limits of size, extending from a considerable magnitude to a small or

even minute bulk. These remarks, however, apply chiefly to the envelopes and extrinsic parts of the ovum; the essential parts, namely the "germinal vesicle" and "germinal spot," preserving a very constant uniformity of size and minuteness throughout the series.

Regarding the constant and unvarying occurrence of the elements of sexual reproduction throughout the entire animal series, there is now little reason to entertain any doubt. The earlier ideas entertained on this subject did not assume the presence, in the lower forms, of organs strictly homologous and analogous with the ovaria and spermaria of the higher members of the series; but extended generalisation and research have fully proved in every instance, save in the *Protozoa*, the presence of true reproductive elements. And even in the case of *Protozoan* forms, there appears reason to believe that they are not entirely destitute of means, whereby a process very nearly resembling that of true sexual reproduction may be performed. Modern research has demonstrated the existence in the *Protozoa* of a developmental process, which, so far as the mere exhibition of phenomena is concerned, appears to imitate and fulfil, in the closest manner, the ascertained conditions and stages of development in higher forms. And if the "nucleus" and "nucleolus" of the *Protozoa*,—structures of almost invariable occurrence throughout the sub-kingdom (Fig. 22, A, *n*)—be considered equivalent to, and homologous with, the ovarium and spermarium of other animals, there can be little doubt that the phases of reproductive development witnessed in those lower forms are essentially those in which, as true animal forms, we should expect them to participate. The community of the process of development and reproduction, so far as all other animals are concerned, would tend to strengthen the belief and supposition that the *Protozoa*, in addition to the ascertained asexual modes of reproduction, should also possess the means for carrying on the truly sexual form of the process.

The subject and phenomena of development admit

of a natural division into three successive groups or stages. The first of these divisions or stages includes those primary phenomena which are exhibited from the moment of impregnation, to the stage in development known as the "formation of the blastodermic membrane." The second and succeeding stage may be conveniently considered as including those phenomena and actions which mark the evolution of the new being, from the first appearance of the special and characteristic features of the embryo to the termination of embryonic life in its "birth," when the period of development proper may be said to end. The third stage or period includes the consideration of those ulterior changes, in form or structure, which the new being may undergo between the period of birth and the assumption or attainment of the adult, mature, and perfect form. This latter stage, therefore, embraces the investigation of the phenomena of "nutritive development" or "growth," and may be said in this way to be somewhat intermediate between the processes of reproduction and development on the one hand, and that of ordinary nutrition on the other.

To the details included under each of these three divisions we may devote such attention as the limits and nature of our present inquiries will allow; since it must be borne in mind that the present subject involves considerations of a highly technical nature, and which may more properly be considered as falling to the province of the comparative physiologist. Still it is necessary for the due information of the beginner in zoological studies, that some general ideas on the subject of development should be obtained; the clearer and better appreciation of many systematic points relating to this process being thereby greatly facilitated.

The first or primary stage of the developmental process extends from the time of impregnation of the ovum to the period of formation of the structure known as the "blastodermic membrane," or simply as the "blastoderm." The changes and phenomena observed in this first stage are essentially the same in the development of the ova of

all animals; and therefore, by gaining a correct idea of the primary process in any one animal form, we become acquainted with the essential changes which take place in the early development of the ovum of any other animal. A very remarkable community of type is thus characteristic of animal development in its primary stages; and this fact, to be presently exemplified, is particularly worthy of being borne in mind; since its due recognition serves to refute and correct certain ideas and theories which formerly gave rise to much misconception regarding the entire subject of development.

We thus become aware of the important fact, that the ovum of any vertebrate, mollusc, annulose animal, cœlenterate,—and in all probability of any protozoön also,—exhibits in its earlier development a series of changes exactly corresponding in kind to those observed in the ovum belonging to any higher or lower type or sub-kingdom. The precursory phenomena observed in the ovum of the Mammal, in this way, correspond to those witnessed in the development of the *Cœlenterate Molluscous*, or of any other impregnated animal germ. Development in its earlier stages is thus essentially and invariably *general*. The changes therein observed are common to the entire animal series. Where differences exist, they are merely those of degree, and not of kind. Variations in the manner in which the plan of development may be executed, depending upon slight structural modifications, either in the ovum or in the circumstances of its development, do not affect the primary and typical course through which that development in its early history must proceed.

To the stages included in this first or primary development the collective term of "segmentation of the yolk" has been applied. As implied by this term, the process chiefly affects the "yolk mass" or "vitellus" of the "ovum;" and it also includes in its extent the "germinal vesicle" and "germinal spot," in which latter structures the essential parts of the ovum have been already remarked to reside.

In the ovum of the mammal, after impregnation, the initiatory stages of development are ushered in by the disappearance of the "germinal vesicle" (Fig. 21, C, *c*), and its contained "germinal spot;" the place of the

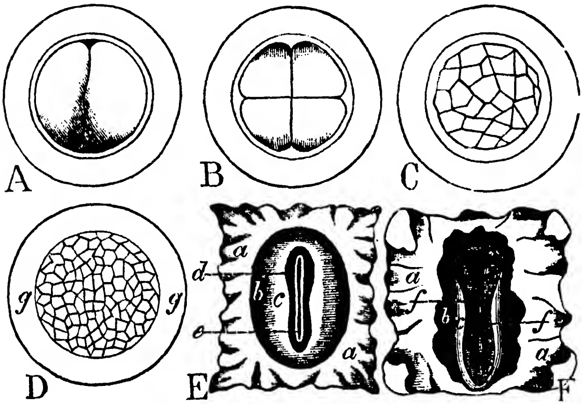

Fig. 25. Development of Mammalian Ovum.

A, First stage of segmentation of mammalian egg, showing its division into two halves. B, Second stage, in which the two primary segments are divided to form four. C, More advanced stage, in which the process of division has produced numerous segments. D, Complete segmentation of egg, known as the "mulberry-like condition:" *g g*, "zona pellucida" or "vitellary membrane." E, Progress of development as seen in ovum of dog (after Bischoff): *a a*, germinal membrane; *b*, area vasculosa; *c*, area pellucida; *d*, dorsal laminæ; *e*, primitive groove, bounded by the substance from which the cerebro-spinal nervous system is formed. F, Further development of E (Bischoff): *a a*, *b*, layers of germinal membrane; *c*, area vasculosa; *d d*, dorsal laminæ: *e*, placed on primitive groove, showing at its upper portion a dilatation corresponding to the primitive divisions of the brain; *f f*, vertebral plates or rudimentary vertebræ.

primary vesicle or cell, according to the majority of competent opinions, being taken by another and newly-formed cell, also of minute structure, and to which the general name of "embryo-cell" has been given. This "embryo-cell,"—so termed, because, from subsequent changes in

its substance the future being may be said to be evolved —at first bears the same relation to the "yolk" as did the germ-vesicle and spot. Around the "embryo-cell" the yolk speedily gathers, and then, by a process of "cytogenesis" or cell-multiplication, we find the embryo-cell and yolk to exhibit a process of cleavage, division, or segmentation. The entire contents of the ovum now begin to divide primarily into two parts (Fig. 25, A); these two primitive segments soon resolve themselves into four (B); the four become eight; the eight sixteen; and this process of successive and increasing multiplication continues, with corresponding diminution in size of the segments, until we find the contents of the entire ovum finally presenting the appearance produced by the high degree of segmentation, and known as the "mulberry-like" condition of the egg (C D).

The "zona pellucida" or "vitellary membrane" (Fig. 25, D *g g*), still encloses the "mulberry-mass," and the next stage consists in the conversion of the segments of this mulberry-like condition into true cells by the formation around each segment of an outer envelope or cell-wall; the included portion of the yolk forming the cell-contents, whilst the little segment itself occupies the position of the central particle or "nucleus."

These newly-formed cells, which thus result from the segmentation of the yolk, now tend to arrange themselves, as represented in Fig. 26, A, *b b*, around the external surface or periphery of the yolk; there to form a membrane or cellular structure of considerable thickness, lining the internal aspect of the "vitellary membrane" (Fig. 26, A, *a a*), and leaving the interior or central portion of the yolk filled with a clear albuminous liquid. Thus we find the ovum in its present stage to consist, firstly, of the outer and original "vitellary membrane" (*a a*); secondly, of an inner membrane (*b b*), formed by the aggregation, near the periphery of the yolk, of the primitive cells resulting from its segmentation, and variously known as the "germinal membrane," "blastoderm," or "blastodermic vesicle," (Bis-

choff); whilst, lastly, we have the interior of the ovum occupied by the clear fluid already referred to.

With the formation of the "blastoderm" or "germinal membrane," the first stage of development may be said to terminate, and up to this point, therefore, the phases of development through which we have traced

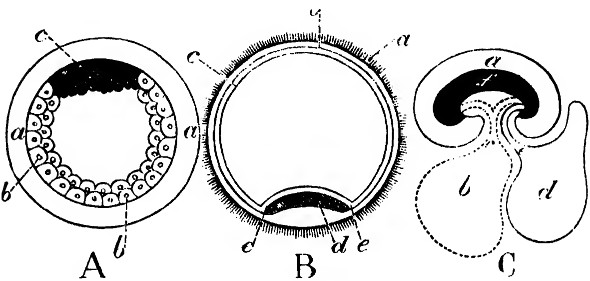

Fig. 26. DEVELOPMENT OF MAMMALIAN OVUM.

A, Formation of "blastoderm" or germinal membrane (*b b*), after complete segmentation, and appearance of germinal area (*c*): *a a*, vitellary membrane. B, Further development of ovum, showing vitellary membrane (*a*), covered with villosities, and constituting the "chorion;" *b*, cutaneous or serous layer of germinal membrane; *c*, mucous layer of germinal membrane; *d*, further development of germinal area to form the embryonic mass; *e e*, elevation of serous layer to form the dorsal laminæ. C, Relation of the embryonic sacs: *a*, inner layer of amnion, immediately investing the embryo (*f*); *b*, umbilical vesicle with its vitelline duct (*c*); *d*, allantois and its duct or "urachus" (*e*), which afterwards becomes the urinary bladder; *f*, embryo. (The figures are purely diagrammatic.)

the Mammalian ovum are common in a greater or less degree to the ova of all other animals. The succeeding series of changes, the consideration of which belongs to the second division of our subject, commence with the formation, at one point of the blastoderm, of an opaque spot (Fig. 26, A *c*), known as the "germinal area" or "area germinativa." This "area" becomes the seat of the more special phases of development, which the second division of the subject will lead us to consider.

Whilst, therefore, the ova of all animals exemplify the same stages of development up to the period of mul-

berry-segmentation and formation of the blastoderm, the similarity or homogeneity of developmental phases stops short at this point; and the development then assumes the ulterior phases characteristic of the particular type of being about to be evolved from the germ. Development up to the period of formation of the blastoderm is thus general to the entire animal series. After this period has been reached, the development becomes *special;* and the succeeding progress of events tends still further to differentiate and identify the special and distinctive features of the new individual. The process of development, may, in this way, be roughly compared to a journey made for a certain period of its extent along one single thoroughfare; but this primary road may be supposed at a certain point to resolve itself into several paths, each of which leads from the common point of divergence, to terminate in a point very far removed from the ending of any of the other paths. The common road corresponds to the primary process or earlier stages of development; the common point of divergence represents the stage of formation of the blastoderm; and the diverging paths represent the various tracts or directions, that is, the various sub-kingdoms or types, the distinctive characters of which will be evolved by the subsequent progress of development.

On the proper appreciation of these points depends the clear conception of Von Baër's great law of development, the import of which lies in the enunciation of the principle we have just been enforcing—namely, that "development proceeds from the general to the special," or that 'the more special and characteristic features, progressively evolve themselves out of the more common and general.' The true and full import and value of such a generalisation is best observed when we consider the erroneous nature of the views and theories which its discovery tended to suppress. Thus, it was formerly supposed, that—taking the case of the human embryo as an example—the ovum of man passed in its development through successive phases, each of which corresponded to

the *adult* or permanent condition of the inferior types of structure seen in the animal series. Or, referring the case to its actual details, it was supposed that the human embryo in its earliest stage of development corresponded to the simple protoplasmic body of the *Protozoön;* then as development proceeded, it was believed to evolve the features of the *Cœlenterate;* next appeared the characters of the *Annulose* animal; then it became like a *Mollusc*, and finally evinced the characters of the *Vertebrata*, passing in its latter stages through the successive forms of the fish, reptile, bird, and then assuming the aspects of the mammal and of man.

Such an idea is therefore embodied in Serres' phase, that "human development or organogenesis is a transitory comparative anatomy, as, in its turn, comparative anatomy is a fixed and permanent state of the organogenesis of man." In other words, the human ovum in its development exhibited a moving or panoramic view of the leading types of structure seen in the animal world; whilst these types, in turn, presented us with fixed views or stages of the progress of embryonic development in man. Such a theory, if proved to be true and worthy of belief, would materially tend to support and strengthen the hypotheses of evolution; since the embryology of the human form would present us with evidence of the gradual evolution of the higher forms from lower types of structure, substantiated and repeated in the cycle of development itself. But clearer views of the bearings of morphology upon development have shown us that the fixed structural type of an organism becomes demonstrable at a very early period in its embryonic history; that period corresponding to the formation of the "blastoderm;" and the evolution being thus not one of successive types, but in reality of the one and particular type to which the ovum belongs, and of which, consequently, the future being will become a member.

Thus the human embryo, immediately after the formation of the blastoderm, evinces the special characters of the vertebrate type of structure alone; and the pro-

gress of development only tends the further to specialise the already fixed and distinct type, and to develop the characteristic features successively of the mammal and of man. Similarly with the ovum of the Fish, Amphibian, Reptile, or Bird. The vertebrate type, and no other, is first evinced after the point of divergence common to all ova has been reached; and thereafter development specialises itself most highly in the case of the Bird, next in the case of the Reptile, still less highly in the case of the Amphibian, and least highly of all in the case of the Fish.

We thus see that not only is the type of structure to which any animal form belongs, distinctly specialised in the first instance, but its exact place and rank in the type itself are further determined by the degree of specialisation to which development may proceed. The first phase or tendency of development is therefore a morphological one, whilst its second phase is as distinctly physiological. In this way are the respective features of type, class, order, genus, and species, successively evolved. Hence, Von Baer's generalisation marks a significant era in the progress of philosophical biology. It gave a fresh impetus to the progress of research into the phases of development throughout the entire animal series; and at the same time constituted a new and important test and aid for the further generalisations and laws of morphology and physiology.

The unity of type, as displayed by the process of development, is further exemplified by instances in which the adult and permanent condition of a form low in the type is represented by the early or embryonic stages of another animal belonging to the same type or sub-kingdom, but of higher organisation than the former. Thus the young condition of a Crab, one of the higher *Crustaceans*, resembles the permanent condition of many of the lower Crustacea. And among the *Mollusca*, we find the well-known example of the young condition of many *Gasteropoda*, representing the permanent and adult condition of the *Pteropoda*—the former class represented

by the Whelks, Snails, Sea-Lemons, etc.; whilst the latter group embraces a number of forms of minute size, which swim on the surface of the sea by means of a pair of wing-like organs or "fins."

Development, however, in the case of the crab becomes more highly specialised than in the case of the lower *Crustacean*. And, similarly, in the *Gasteropoda* the process of development, which at one stage produced a form resembling the adult *Pteropod*, continues beyond this stage, and eventually evolves a form of a much higher organisation than the last-mentioned animal. Nor has such a series of phenomena escaped the notice of the evolutionist, who, naturally enough, enlists these observations in the defence and support of his theory. But the transient likeness of a higher form to the mature state of a being lower in the type or sub-kingdom is susceptible of explanation on the ground of mere unity of type, and apart from any considerations respecting the common or connected origin of the forms. The likeness implies a morphological relationship apart from questions of origin or descent; and the explanation of the evolutionist is as insufficient to account for such resemblances as it is to explain why certain forms should evince a higher degree of specialisation than others, or why, for that matter of it, a *Vertebrate* ovum as yet unspecialised, should in one case tend, by development, to evolve the body of a fish, or, in another case, the form of a man.

The consideration of the second of the three stages into which we divided the process of development leads us to notice, in brief detail, the phenomena exemplified in the production from the primitive blastoderm of the characteristic embryonic form; and of the subsequent phases which culminate in the full development and birth of the embryo.

The first stage of development terminated with the formation of the blastoderm, and we had traced the production from the blastodermic surface of the "area germinativa" or "germinal area" (Fig. 26, A, *c*), in the substance of which the form of the embryo first appears. The blas-

toderm itself now becomes the seat of active change. We observe its rapid increase in thickness by the development of its cell-structures; and finally we can trace its subdivision into two distinct layers, each of which forms a primary and formative tissue in the embryonic form.

The outer or upper of these blastodermic layers is termed the "serous," "cutaneous," or "animal" layer (Fig. 26, B, *b*), since from this structure the rudiments of the vertebral column, the cerebro-spinal nervous axis, and the epidermis or general skin of the body are produced. The inner layer is known as the "mucous" or "vegetative" layer (Fig. 26, B, *c c*), and from this latter the general textures of the alimentary or nutritive system are formed. Latterly, and between these two primitive layers, a third and intermediate layer is developed, and to this third structure the term "vascular layer," or "vascular membrane," is given; the blood-vascular or circulatory apparatus, and other structures, being evolved from this particular source.

By the specialisation of these primary layers the entire embryonic form is ultimately produced, but the changes that ensue on the formation of the blastoderm have their more immediate seat in the "area germinativa," which we have already seen to be formed in the substance of the "germinal membrane" (Fig. 26, A, *c*). Within the "germinal area" a clear spot is next observed to form. This latter has, from its appearance, been accordingly termed the "area pellucida" (Fig. 25, E, *c*); and around the "area pellucida" the cells combine to form a marginal border, known as the "area vasculosa" (Fig. 25, E, *b*).

The "serous" and "mucous" layers of the germ both participate in the formation of these structures; but it is in connection with the "serous" layer of the "germinal area" that the next phase of development is observed to occur; this latter phase consisting in the formation of the so-called "primitive groove" or "trace" (Fig. 25 E, *e*). By the "primitive groove" is meant the shallow groove (*e*) formed in the centre of the "germinal area," and which lies between two projecting ridges of the serous

layer (Fig. 26, B, *e e*), known as the "laminæ dorsales." Gradually these "laminæ" (Fig. 25, E, *d*) alter in form, and in consequence change the conformation of the "groove" they enclose, until they finally become of an elliptical shape, and unite together, thus converting the shallow "groove" into a tube or canal.

In the floor of the tube so formed the rudiments of the brain and spinal cord (Fig. 25, F, *e*) are next developed. Whilst beneath the floor of the tube the embryonic structure known as the "notochord," or "chorda dorsalis" (*e e*), is produced; this latter structure being replaced in greater part, and as the being advances towards maturity, by the vertebral column or spine. The first rudiments of the vertebral column itself make their appearance at this stage on the sides of the "primitive groove" in the form of square-shaped cells (Fig. 25, F, *f f*), which are known to the embryologist by the name of "primitive vertebræ."

The "dorsal laminæ," therefore, form the upper or "neural" tube of the *Vertebrate* body, and from the "laminæ dorsales" other two processes, or "ventral laminæ," are in turn produced downwards. And these latter, uniting below in the middle line, form a second tube parallel with the first-formed or "neural" canal. This second tube constitutes the "visceral" tube of the *Vertebrate* body, and forms the thoracic and abdominal cavities of the future being. In the primitive visceral cavity thus produced the rudimentary digestive tract is developed from the "mucous" layer, and the general outline of the body may in this way be said to have been sketched.

In connection with these three distinct layers of the germinal substance, of which the embryonic form is at first exclusively composed, we have to notice three distinct "sacs" or "vesicles," which make their appearance at an early stage of development, and which subserve each a special function in the embryonic economy. From the outer portion of the "serous" layer of the embryo the first of these sacs takes origin. This sac or vesicle is of a double nature, the outer fold becoming continuous with

the "vitellary membrane," whilst the inner fold forms a protective sac, in which the embryo is contained. This serous sac is known as the "amnion" (Fig. 26, C, *a*), and it secretes a fluid termed the "amniotic fluid," or "liquor amnii," in which the embryo (*f*) floats and is contained.

The mucous layer, in turn, gives origin to the "umbilical vesicle" or "yolk-sac" (Fig. 26, C, *b*); a structure which communicates with the abdominal cavity by means of a constricted neck-like portion, known as the "vitelline duct" (*c*). The "umbilical vesicle" contains the unabsorbed portion of the yolk or "vitellus," and contributes directly to the nutrition of the embryonic form.

Lastly, from the "vascular" or intermediate layer of the "germinal membrane," a third sac is developed, and to this latter vesicle the term "allantois" has been applied. The "allantois" (Fig. 26, C, *d*) springs from the lower surface of the embryo, and communicates with the digestive tract, and with the rudimentary kidneys, or "Wolffian bodies," as they are termed. The function of the "allantois" is undoubtedly that of a respiratory organ, and in this capacity it serves to bring the blood of the embryo in contact with the external air, thus providing for its due aëration. In Birds the "allantois" assumes a large size and a high importance in the economy of the embryo. But in most *Mammalia* we find the "allantois" in connection with the "chorion," giving origin to a new and distinct structure, known as the "placenta;" the latter organ assuming the functions which formerly devolved upon the "allantois" itself. The portion of the "allantois" contained within the abdominal cavity, together with its pedicle or "urachus" (*e*), become finally converted, by the process of ulterior development, into the urinary bladder of the adult form.

The last structure in connection with the purely embryonic appendages which may here be alluded to is that known as the "chorion." This term is applied to the external envelopes of the embryo, constituted in chief by the ultimate development of the "vitelline membrane of the germ." The outer surface of the "chorion" at an

early stage of development becomes shaggy or villous in appearance, from the presence of a number of minute projections or tufts (Fig. 26, B, *a*). These tuft-like processes, or "villi," gradually become more complicated and branched, and appear to subserve the function of nutrition in its earliest phase, by absorbing from the maternal surfaces the fluids necessary for the sustenance of the embryo. And finally, in the Mammal, we find the "allantois" becoming associated with the "chorion," to form the structure already alluded to under the name of the "placenta; on which latter organ the function of respiration, in the later stages of embryonic existence, chiefly, if not wholly, devolves.

The tracing, from the primary tissues, of the after-development of the various organs and systems of the body, falls to the province of the comparative anatomist and physiologist; and such an inquiry presents details of too technical a character for enumeration or description in the present work. The second stage progresses from these more general to more special developments, and terminates in the "birth" of the fully-developed embryo; that is, with its evolution from the maternal surfaces at a period when it is fitted to carry on the separate existence of the individual. Embryonic life thus ends, and individual existence begins.

The period at which the birth of the embryo may take place varies greatly throughout the animal series, as also does the entire duration of the developmental process. The relationship between the parent-body and the embryonic form also varies widely throughout the animal creation. Thus, in the lower forms of animal life, the ova, in the majority of instances, are not only impregnated external to the body, but the entire process of development is carried on in a manner entirely independent of parental care. To this rule there are, among the lower forms, undoubted exceptions; but the fact is, notwithstanding such exceptional cases, of the most generally applicable kind. In the lower forms we therefore find nothing approaching to that intimate connection between

parent and offspring which is witnessed among the higher *Vertebrates.*

The *Vertebrata* exhibit in turn wide differences in the process of development, so far at any rate as relates to the duration of the developmental period, and to the relation between the parent and the impregnated germ. Thus in the Fishes, as constituting the lowest class of the Vertebrate sub-kingdom, the ova are generally impregnated without the body, and the subsequent development of the fecundated germ also takes place independently of, and external to, the parent-organism. Those forms which thus produce eggs, from which the young are afterwards developed, are known as "oviparous" animals. Some fishes and certain reptiles are "ovo-viviparous;" that is, the eggs are retained within the parent-body until the young are ready to be produced or hatched. In Birds, we find the "oviparous" mode of development united to a peculiar exhibition of parental care, by means of which the eggs are hatched through the warmth of the parent-body. In the bird the process of external development is carried out on the part of the parent to the same extent that internal development is shared in by the parent among the *Mammalia.* Impregnation in such cases, as also in the "ovo-viviparous" mode of development, may, and generally does, take place within the body of the parent, the ova being fertilised by the introduction within the female body of the male element. Lastly, in *Mammalia,* we find the "viviparous" mode of development exemplifying the highest form of relation between parent and embryo. Impregnation in this latter case is invariably internal, and the development of the ovum is also carried on within the maternal organism until the period of embryonic maturity is attained, when the new being is born alive into the world; this last feature constituting the essential part of the "viviparous" form of development. In conformity with this high specialisation of the process, we find corresponding adaptations of structure both in the ovum and in the structure of the parent-organism; these adaptations contrasting in the most

striking manner with the analogous arrangements witnessed in lower forms. It is, however, peculiarly the province of the systematic zoologist to investigate the relative homologies and structure of the reproductive systems throughout the series of animal forms.

Finally, it is to be borne in mind that the mere manner of impregnation, or mode of development, is of secondary importance so far as the recognition and distinction of the truly "sexual" form of the reproductive process is concerned. We have already seen that the essential part of this process consists in the mere contact of the sperm-cell of the male with the germ-cell of the female; and it is therefore immaterial to the performance and constitution of the sexual reproductive act whether the contact or impregnation be effected external or internal to the body, or whether development be carried on without or within the parent-organism. The observation thus detailed will be found of value, since the relations between the processes of reproduction and development are exceedingly susceptible of mistake and confusion.

It has already been pointed out that the "germ vesicle" and "germinal spot," together with the "yolk" and "vitellary membrane," constitute the essential parts of every true ovum. And whilst this general statement is thoroughly correct, it is at the same time worthy of remembrance that the relative development of these parts, both before and after impregnation, varies greatly throughout the animal series. The comparative physiologist has accordingly been accustomed to divide ova into three great groups, taking the relative development and transformation of the "yolk" as the basis of his classification. Thus the first group includes those ova in which the entire yolk becomes segmented in the process of development; and of this group the egg of the Mammal may be cited as a typical representative. The second group, typified by the egg of the bird, and by that of many Invertebrate forms, embraces those ova in which only a portion of the yolk undergoes segmentation. Whilst the third group includes ova in which the pro-

cess of cleavage, relatively to the yolk, appears to vary greatly; the results of segmentation being, in a certain degree, intermediate to those seen in the other two groups. The generally large size of the yolk in all classes of the animal series, save the *Mammalia*, has reference to the peculiar mode of development of the lower forms. The yolk constitutes, in all save the *Mammalia*, the source of nutritive supply to the embryo, whilst in these higher forms the embryonic form is nourished directly from the maternal tissues and fluids,—the large size, as well as the nutritive function of the yolk-mass, being thus rendered entirely useless in the Mammalian economy.

In briefly tracing the progress of development throughout the great subdivisions of the animal series we have firstly to consider the *Protozoa*, as in all probability presenting us with the same series of primary stages of development that we observe in the other sub-kingdoms; although further research is required ere we can make this statement as one of absolute certainty. Analogy alone would lead us, as previously remarked, to refer to the typical process of segmentation certain phenomena observed in the reproductive processes of the *Protozoa*.

Thus in *Gregarina*, one of the lowest of *Protozoan* forms

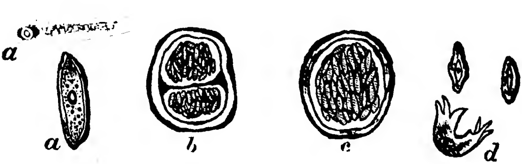

Fig. 27. GREGARINIDA.

Development of *Gregarina*: *a a*, adult *Gregarina*; *b*, encysted condition of *Gregarina* undergoing the reproductive process, showing "pseudonavicellæ" contained within the cyst; *c*, more advanced stage of *b*, the septum or partition having disappeared; *d*, free "pseudonavicellæ" escaping from cyst (*c*) by its rupture.

(Fig. 27, *a a*), we observe a series of phases in the cours of the reproductive process which very closely resemble

the stages of yolk segmentation in the ova of higher forms. Two *Gregarinæ* may be observed to coalesce together—or the series of changes about to be described may take place in a single individual—and the contained nucleus is observed to disappear. The organism now assumes a globular or spherical form, and appears to consist of a cyst-like body surrounded by a thickened wall. Soon the interior of this cyst becomes divided, apparently by a process of segmentation, into a number of spindle-shaped bodies (*b c*), to which the term "pseudonavicellæ" has been applied. By the subsequent rupture of the cyst, the "pseudonavicellæ" escape (*d*), and appear to require but little additional development to change them into the likeness of true *Gregarinæ*, resembling in every way the organism from which they sprang.

In considering the above and similar phenomena there does not appear any insuperable difficulty or objection to the idea that a lowly-specialised form of the developmental process of higher forms is therein represented. Analogy would thus seem to indicate that the *Gregarina*, in its reproductive phase, assumes the functions and form of a true ovum; the contained nucleus and nucleolus corresponding to the germ-vesicle and germinal spot. The disappearance of the nucleus would appear to represent the dissolution of the "germinal vesicle;" whilst the succeeding process by which the pseudonavicellæ are produced might, and not inaptly, be regarded as corresponding to the process of ovular segmentation. The stage of rupture of the Gregarina cyst would similarly correspond to the formation of the blastoderm in the ordinary ovum; the *Protozoan* development proceeding no further than this stage, but resulting, in virtue of its low degree of specialisation, in the simple evolution and production of the new beings.

In other and higher *Protozoa* a similar, and, in some cases, a better marked series of phenomena has been observed. Although, therefore, it would be inadmissible and premature to assert that the sexual process of reproduction and of ovular development is actually carried on

in the *Protozoa*, we are sufficiently justified in stating that there are strong reasons, analogical and otherwise, for assuming that the processes known and ascertained to be present without exception in the higher groups of animal life, should be at least represented in these humbler forms. We cannot expect, it is true, that the process in the *Protozoa* should be as highly specialised as in the higher types. *Protozoan* development cannot be assumed or expected to attain the degree of specialisation evinced by that of the *Cœlenterate*, any more than the development of the *Cœlenterate* could be expected to be of as complicated or advanced a nature as that of the *Vertebrate*. It would appear, however, that this expectation has led observers to overlook the actual details of the process as it occurs in the *Protozoa*; and accordingly we find the idea strongly promulgated that the process of sexual reproduction, and of consequent development, is entirely absent or wanting throughout the lowest sub-kingdom or type of structure. But when we carefully notice the actual phenomena, and also observe the sequence in which these phenomena appear, it must be allowed that they more nearly approach and imitate the process of true ovular development than any other process in the living organism. If, on the contrary, we reject even the mere analogy of this process with that of ordinary "ovular" development, we necessarily place the *Protozoa* as unnatural exceptions to the most general and universal of rules; and, at the same time, leave the nature of the process observed in these forms entirely unexplained and unaccounted for.

The higher and succeeding sub-kingdoms present us with the characteristic phases of development we have already investigated. In the *Cœlenterata* the primitive blastoderm, formed after the segmentation of the yolk, divides into the two typical layers, the inner or "mucous," and the outer or "serous" layer. Cœlenterate development, beyond mere consolidation and fixation of external form, proceeds no further than this. The inner layer of the primitive blastoderm goes to form the "endoderm"

of the perfect Cœlenterate (Fig. 8, *b*), whilst the outer blastodermic layer develops into the "ectoderm" or outer tissue of the perfect organism (Fig. 12, B, *a b*). There results, therefore, from this development, no specialisation of either neural or hæmal centres, and but a very imperfect development of the alimentary tract; since we have already seen, in our definition of the *Cœlenterate* type (Fig. 12, B), that the stomach-sac or digestive cavity (*e*) of these forms communicates freely with the cavity of the body (*f*).

The cavity formed in the early Cœlenterate embryo, after the separation of the blastodermic layers, corresponds to the somatic or body cavity of the perfect organism. The embryo would appear to be developed generally from the greater portion of the fertilised ovum; the initiatory stages of development being ushered in by the division or segmentation of the germ-vesicle. The embryonic form usually appears as a free-swimming ciliated body (Fig. 24, E), in the history of which the changes already described are soon manifested, and finally result in the production of the new being. The ova in *Cœlenterata* are further said to be, in the majority of instances, unprovided with a "vitellary membrane."

So far, therefore, as *Cœlenterate* development proceeds, it appears to present but little advance upon the phases seen in the *Protozoa*, the developmental nature of which phases we have already suggested and advocated. The *Protozoan* path, which diverges from the common point in the previously single developmental road, stops short at a very limited distance from the point of divergence; whilst the *Cœlenterate* road proceeds a little further, and leads us to more specialised detail. But the *Cœlenterate* path, in turn, stops short of the tracts leading to higher types of structure at a stage of its extent even earlier than that at which the *Protozoan* road ceases to be comparable with that of the *Cœlenterate*.

In the *Annulosa*, after the segmentation of the ovum, we find the characteristic and special phase of development to result in the transverse division of the primitive

blastoderm ; the distinctive body-division of the annulose form being thus foreshadowed. The neural or nervous region becomes first developed, and the mouth soon comes to open on the lower or neural aspect of the body, towards which side the limbs are also turned.

In the *Mollusca*, the blastoderm is destitute of the definite segmentation so typical of the preceding type, and the hæmal or blood-vascular centres appear first in order of development. The mouth in this type of structure also opens on the neural aspect of the body.

Finally, in the *Vertebrata*, we have noticed that the appearance of the "primitive groove," with its dorsal and ventral "laminæ," constitute the special features of Vertebrate development, as distinguished from that of all other forms ; the mouth in *Vertebrata* being developed on the hæmal aspect of the body, towards which side of the body the limbs are directed. The neural region is first developed in the evolution of the Vertebrate form.

The third stage into which the subject of Development may be divided has reference to certain processes or phases incidental to the early life of many organisms, whereby they undergo a secondary development, generally possessing a more or less intimate connection with the nutrition and growth of the individual, and with certain subsequent and ulterior functions which the individual may be called upon to subserve. Viewed in this light, the third division of the subject may appropriately be termed that of *Nutritive Development*.

The principal series of phenomena which fall to be considered under this third division are those included under the general term of "transformation" or "metamorphosis." By this term we imply the series of changes through which an organism passes after its birth, and in its transition from the immature state in which it was produced, to the attainment of the mature and adult form. The form which undergoes this metamorphic process is therefore produced or evolved from the egg in an immature state of development ; the secondary development which it undergoes roughly representing or corresponding to the

latter period of the developmental process, which, in ordinary cases, is carried on within the egg. The phenomena of "metamorphosis" are intimately associated with the process of nutrition, in that we see these phenomena most fully exemplified in cases where, from rapidity of development, or from insufficient nutritive supply on the part of the parent, or from both of these causes, the young form is prematurely introduced into the external world, in so far, at least, as its nutrition and growth are concerned. The process of "metamorphosis" also bears, as will be presently shown, a close connection with that of reproduction; inasmuch as the reproductive organs of the form thus prematurely produced partake of the imperfect development common to the entire form; and these latter organs, during the process of nutritive development, attain their full perfection, and thus arrive at maturity only when the fully-mature state has been reached. Hence the form which is the subject of the metamorphic process is generally sexless; or, if the reproductive organs be present, they are functionally useless. On the other hand, when the function of nutrition has been in a manner concluded, and when the being assumes its perfect and adult phase of existence, the reproductive function is then perfected and subserved. The probationary period passed in the metamorphic process is thus devoted to the assumption of those nutritive energies which the performance of the reproductive function will tend to waste and dissipate. We here notice an illustration of the law alluded to when treating of reproduction, and which has been elucidated by Spencer, Carpenter, and others—namely, that the functions of nutrition and reproduction act antagonistically and in opposition to each other.

As implied by the term "metamorphosis," the immature organism undergoes successive changes of form and structure; these changes affecting not merely superficial organs and parts, but involving the deeper-seated structures of the body. Although, therefore, the process of metamorphosis has been compared to the latter stages of ordinary development, the analogy between the cases is

by no means perfect or complete. Thus, in the course of ordinary development, we have new parts or organs added successively to those which were already formed; these developed structures, with a few changes dependent on the process of ordinary growth, remaining to form definite parts, not only of the embryo, but also of the adult being. But in the metamorphic process we find that the embryonic organs characteristic of one stage of the process generally disappear, and are replaced by new and totally diverse structures, morphologically, as well as functionally, different from those of the preceding stage. And the process thus involves more than that of ordinary development. It necessitates and implies almost complete change, not only of external form, but also of internal structure; the phases of ordinary development tending to produce merely new and stable parts which do not alter, save in the processes of nutrition and growth.

Examples of the process of "metamorphosis" are plentifully scattered throughout the *Invertebrate* series. Among the *Annulosa, Annuloida, and Mollusca*, we find many illustrations of the process, the first-mentioned group probably presenting the greater number, and at the same time the most typical examples.

A familiar illustration of the process of metamorphosis is witnessed in the development of the Butterflies and Moths (Fig. 28), or in the case of the Beetles. From the egg of the Butterfly comes forth a crawling grub or caterpillar, known technically as the "Larva" (*a*). The preliminary stages of development have resulted in the production of this form, the structure of which is comparable in detail to that of a highly-organised worm; a creature this as unlike the perfect insect as could well be conceived. And as it resembles not the perfect form in appearance, so neither has it any kinship with its life or habits. It possesses a mouth fitted for mastication, and a digestive system adapted for the elaboration of a dietary different from that of the perfect form. It is provided with six true legs, and also with a number of fleshy locomotive appendages, known as "prolegs." And it is also

generally furnished with an organ for the production of silk-material, which is used in the latter stage of its larval existence, to form a case or " cocoon " for its body.

The larval form, so constructed, spends its life wholly in the performance of the nutritive process. It eats voraciously, and usually increases enormously in bulk, changing its skin many times in the course of its exist-

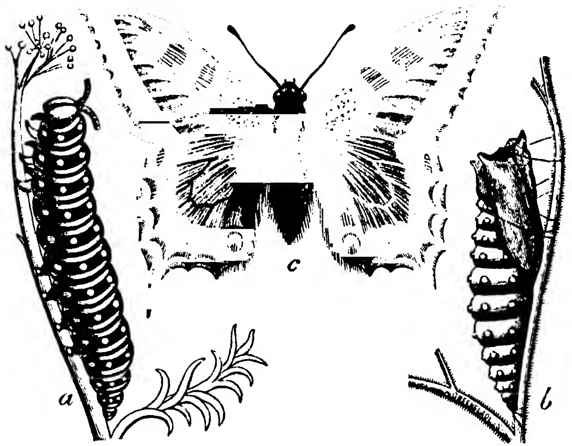

Fig. 28. DEVELOPMENT AND METAMORPHOSIS.

Metamorphosis of the Swallow-tailed Butterfly (*Papilio Machaon*): *a*, Larva or Caterpillar; *b*, Pupa; *c*, Imago, or perfect form.

ence, to meet the exigencies of increasing size, the process of moulting being known as that of " ecdysis ; " and so rapidly does it grow, that at the termination of this period of existence it will generally be found to have increased very many times in size from its original dimensions.

The larval stage is terminated by the preparation of a case-like structure or "cocoon," which varies widely in form and nature, throughout the insect-class. And in this cocoon it proceeds to enclose its body, and

thus enters upon the second period of its metamorphic existence.

This second stage is known as that of the "pupa" or "chrysalis" (*b*). Viewed externally, the period would seem to be one of perfect quiescence, but changes of important extent are meanwhile proceeding within the pupa-case. The elements of the larval form are gradually being transformed into those of the adult. The masticatory mouth is being altered to form a suctorial apparatus, adapted for the suction of flower-juices, instead of the trituration of leaves. The digestive, circulatory, and nervous systems also participate in the metamorphic process; the reproductive organs similarly attain their perfect development; the rudimentary legs of the larva are replaced by those of the adult; the wings are now developed; and at the fitting period the pupa-case ruptures, and a bright, new, and perfect form escapes therefrom. This perfect creature, exercising its new-born functions amid the sunlight and flowers, has been appropriately designated the "imago" (*c*).

A cursory review of the phases thus briefly enumerated will divide the life of the insect-form into two great periods, which may be respectively named the "nutritive" and "reproductive" periods. The former is constituted by the period of metamorphosis, in which the whole energies of the form are devoted to its nutritive supply. The reproductive stage is constituted by the life of the perfect insect; and during this period we find the energies of the being devoted to the active perpetuation of the species. And recognising this division of the periods of functional activity in the light of the remarks already made when entering upon the subject of metamorphosis, we lastly observe that the process of metamorphosis is most fully exemplified in those cases where the demands upon the reproductive energies are very great, and where the existence or nature of the perfect form is generally of an ephemeral kind. The life of the perfect insect is, as a rule, of but short and limited duration; and we find this relative arrangement of the nutritive and reproductive periods of its life forming a most

admirable illustration of the adaptive cycle, according to which the whole series of functions in the living organism operate and are arranged.

Among the *Crustacea*, we find the crabs and other forms exemplifying the metamorphic process; whilst among the *Annuloida*, as already noticed (Fig. 13), the *Echinodermata* exemplify a kindred series of developmental phases. In the latter instance we observe the "provisional larva" of the Echinoderm, furnishing a structure out of the materials of which the perfect form is built up and evolved. Such a phase, however, exemplifies the metamorphosis in a less perfect degree than does the case of the insect; the larval form of the Echinoderm being more truly of a provisional or temporary nature, and not possessing the same intimate relations with the perfect form as those borne by the larva of the insect to the adult "imago."

The term "retrograde" or "recurrent" development, is applied to certain cases of development, in which we find the larval or embryonic form presenting us with a structure evidently superior to that seen in the adult and perfect organism; the development of the adult apparently retrogressing from that of the larva. Thus, among *Crustacea*, the *Balani* or "Sea-acorns," and many allied forms, are free and locomotive in their earlier stages, and are then provided with eyes, organs of sense, and locomotive organs, and are otherwise adapted for an active existence. In their adult condition they become fixed and sessile, and are destitute of the organs of sense and appendages with which the embryonic form was provided. This "retrograde development" extends to all the structures of the body save the reproductive organs, which are developed in the adult form alone. In all probability the series of changes thus witnessed, and which are apparently so strange and inexplicable, have a close relationship with the reproductive or sexual phases of these forms; although regarding the exact nature of such a relationship we possess no definite knowledge.

The phenomena of "retrograde development" are also witnessed in cases of the conversion of healthy or normal tissues into diseased or abnormal textures; the pathologist, however, in such cases, being generally able to definitely determine the exciting or predisposing causes of the abnormal action.

The term "retrograde metamorphosis" has been given to a series of changes which a form, in itself of transitional nature, may undergo after the performance of its particular function or functions. Thus in the case of the Medusoid embryo of *Hydroid* zoophytes (Fig. 24, D), we occasionally notice that, after the performance of its reproductive function, the *Medusa* loses its bright crystalline appearance, shrivels up, and presents us with a form curiously altered from that in which we formerly beheld it; and in this state it may continue for a longer or shorter period prior to its dissolving away in the surrounding water.

The terms "retrograde metamorphosis" and "retrograde development" are frequently used as synonymous; but it appears to be more consistent with a correct rendering of their significance and relative meaning to distinguish between these terms. We should thus limit the term "retrograde *development*" to the distinction of phenomena, in which forms as adults, evince a retrogression in development from that seen in their embryonic state; the phrase being thus applied to organisms possessing a fixed, or at any rate more than a merely transitional nature. Thus the young *Balanus* or *Epizoön* is a form of distinct entity undergoing development. And similarly the expression "retrograde *metamorphosis*" should be limited to identify conditions, in which a form, in itself of merely transitory nature, exemplifies a retrogression. The retrogression in the *Medusa* is thus one not of "development," but merely of "metamorphosis;" the metamorphic retrogression in this latter case merely presaging the final dissolution of the transitory form.

CHAPTER XIII.

"Heterogenesis" or "Spontaneous Generation:" Nature of the Subject—Development of Life in an Infusion—Molecules, Bacteria and Vibrios—Doctrine of "Homogenesis" or "Biogenesis:" Nature and Definition—Historical Sketch of the Subject—Doctrines of Redi—Experiments of Needham and Buffon—"Germ Theory" of Spallanzani—Experiments of Schulze, Schwann, Schroeder, and Pasteur—Bastian's "Beginnings of Life"—Comparison of "Abiogenesis" and "Biogenesis"—Lister's Experiments—Conclusion.

THE consideration of the subjects of Development and Reproduction has taught us, or led us to believe, that the pre-existence of a parent-form, or of seeds or germs, is, in ordinary circumstances, necessary for the production of new beings or organisms. In other words, we naturally infer that existing forms of life have been derived, or have taken origin, from pre-existing forms. And such an inference is justified by the ordinary sequence of reproductive phenomena observed in both animal and plant worlds. Yet we have already seen that the paths of biological inquiry are beset with many and strange difficulties; and we have also witnessed the displacement and contradiction of many theories and beliefs, at one time quite as surely fixed, and apparently as worthy of support, as the natural and justifiable supposition that a living form must have had a pre-existing progenitor, in most cases, resembling itself.

The doctrine of "Heterogenesis" or "Spontaneous Generation," however, maintains the occurrence of the production of living beings *de novo;* that is, without the pre-existence of parent-forms, germs, or seeds. The subject before us is therefore one which possesses a great interest for the biological student, and which, in a work

The series of changes and events thus described must be borne in remembrance, since they constitute a typical case for the illustration and explanation of the doctrines, in the consideration of which we are engaged. And the phenomena thus witnessed would therefore appear to partake of the nature of those phases which have been already noticed in discussing the "molecular" origin of the tissues and cell-structures. By the advocates of the "molecular theory of organisation," the organic and vital molecules found in the infusion are accordingly considered capable of gradual aggregation in various ways to form living organisms; which latter, thus produced by the coalescence of the molecules, are said to arise "spontaneously" or by a process of "abiogenesis," that is without the intervention or presence of true ova, germs, or spores, derived from pre-existing forms. Other supporters of the doctrines and tenets of "abiogenesis," without recognising or binding themselves to accept the conditions offered by this "molecular theory," find a sufficient explanation for the origin of living organisms in a fluid infusion of organic matter, in the supposition that the living forms are produced "spontaneously;" or simply by the combination, in virtue of chemico-physical conditions and laws, of the dead, lifeless, and inert particles held suspended in the infusion. And this latter hypothesis will be readily recognised as allied in kind to those physical theories of the origin of life and vitality which we discussed at the commencement of our biological studies.

Such is a statement of the leading and essential ideas included in the doctrine of "abiogenesis;" or, as it was known to the older biologists, the doctrine of "spontaneous generation." The present aspect of the "molecular theory," it must be borne in mind, is not at all analogous to that in which we considered it, as relating to the ultimate constituents of textures and tissues. Since, in regarding the origin from a "molecular bioplasm" of cells and tissues, we assume the existence of a special force and conditions; the force being that of ordinary vitality, and

the conditions those of ordinary development. To assume, therefore, the power of molecules to spontaneously coalesce to form organic beings of definite form and organisation, is to place the "molecular theory" on a widely different footing from that in which we regard it as materially serving to explain the formation of cells and tissues after the process of development has been inaugurated and begun. In the one case we assume the pre-existence of a vital power determined by the ascertained conditions of development. In the other we regard the molecules as of themselves capable of producing and inaugurating the vital action, and of building up, in a manner utterly inconsistent with any known laws of development, the definite forms of living organisms.

As might readily be expected, the supporters of "Abiogenesis" have not had the field of controversy entirely or at all to themselves. On the contrary, they have been hotly and strenuously opposed by a second school of biologists, whose leading doctrine, in opposition to that of "Abiogenesis," has received the names of "Biogenesis" and "Homogenesis;" whilst the supporters of this latter theory have also been occasionally known as "Panspermatists."

The doctrine of "Biogenesis," in contradistinction to that of "Abiogenesis," may therefore be said to rest upon the belief and opinion that the living organisms found in infusions are produced from true ova, germs, or seeds borne by the atmosphere, or contained in the organic matter of the infusion. These germs or seeds, in either case, find in the infusion a suitable medium, and therein develop into the characteristic forms of life, of which they are the early representatives. The infusion is to the floating or contained germs what the soil is to the seed; and the contact of one with the other constitutes the necessary condition for developing the seed or germ into an adult form.

The main features of this latter theory will doubtless be familiar to many readers under the more ordinary designation of the "Germ Theory." The essential tenets of the "biogenesist" are therefore, firstly, the production

of living forms, invariably and solely from pre-existing forms, or mediately through ova, germs, or seeds ; and secondly, the presence of such germs in the atmosphere and in solutions of organic matter. The other subsidiary conditions required and maintained by the doctrine of "Biogenesis" briefly consist in the preservation of the vitality of such germs, under circumstances which would destroy the vitality of ordinary and more highly organised forms of life. Such circumstances are exemplified in the degrees of extreme heat and cold, to which it is believed these germs may be subjected without destroying their vitality, which is thus of a peculiarly "potential" or "dormant" kind.

Such being the respective tenets of each of these great biological doctrines, we may now briefly trace the historical progress of the present subject, with the view of placing ourselves in a fit position to arrive at some clear conception of the relative merits of each theory.

The doctrine of "Abiogenesis" claims the priority over that of "Biogenesis" in point of age and historical or chronological pre-eminence. The ancients were strict "abiogenesists," in that they explained the production of living beings from putrefying organic material, by alleging and believing that they were generated by the decomposition and decay of the organic matter ; or more simply, that life and living forms were produced *de novo* from dead or from truly inorganic material. The circumstances in which this belief originated were of the most natural description ; and the explanation of the origin of living beings thus given appeared to fit accurately with these circumstances, and to leave no room for further argument or controversy regarding them. Thus, for the very typical and oft-referred-to case of the production of maggots in putrefying meat, the ancients, and even philosophers at the beginning of the seventeenth century, had a very ready and apparently exhaustive explanation. The maggots were supposed to be generated or produced from and by the simple decomposition of the decaying flesh ; in other words, they were believed to be "spontaneously"

generated by the putrefactive process in the meat. And we thus observe that the doctrine of abiogenesis, in its earlier aspects, did not solely concern the production of such low forms of life as mere *Infusoria* and allied organisms. On the contrary, animals so high in the scale of being as insects, and even forms of a higher grade still, were believed to be occasionally, and in this way "spontaneously," produced.

In 1638 the doctrine of Abiogenesis may be said to have received its first check, when the experiments of Francesco Redi, a Florentine physician, demonstrated that there were other, simpler, and better explanations of the appearance of maggots in meat than the supposition of their "spontaneous" generation. Redi, directing his attention to the apparently solid facts on which the doctrine was founded, soon saw cause to dispute the validity both of the theory and of the circumstances from which it took origin. Referring to the generation of maggots in meat, he showed that, by placing gauze over the meat, the development of the maggots was prevented, although the process of meat-corruption went on as before. It was obvious, therefore, that the gauze kept back from the meat a something which formerly had free access to it; and ordinary observation soon detected that this "something" consisted merely in the eggs of flies, which were deposited in the putrefying material, and which gave rise, by a process of ordinary development, firstly to maggots, and finally to the mature forms or flies. The production of "galls" and other vegetable growths was accounted for by Redi in a similar manner; and, primitively simple though the method of his experiments may appear to be, it is nevertheless closely and essentially pursued by the experimentalists of modern times.

As might be expected, Redi's refutation of the "abiogenetic" doctrine caused no little consternation and dismay among the supporters of that theory. The refutation of a doctrine apparently so incontrovertible and so firmly rooted, served to change and alter in the most remarkable manner the current of opinion regarding abiogenesis; the

overthrow of the latter theory serving at once to found and establish the rival hypothesis of " biogenesis. And the motto and dictum of Redi, "omne vivum ex vivo," was therefore considered as the triumphant expression of a newly found and universally correct law. Whilst the aphorism of Harvey, " omne vivum ex ovo," more narrowly limits and defines the belief of the biogenesists—essentially the same in these days as it was at the birth of their doctrine—the production of life and of living beings only from pre-existing life, and most generally from the ova, seeds, or germs, of pre-existent and parental forms. Life and vitality are invariably propagated by true descent, and are never specially produced or created *de novo*. Such were and are still the tenets of " biogenesis," a doctrine which for nearly an entire century after Redi's time held the position formerly occupied by the rival and opposing theory.

Meanwhile the growing perfection of the microscope, and the investigation of the lower forms of life, which in Redi's time were almost totally unknown, and the further knowledge of the production of *Infusoria* and allied organisms in artificially-prepared infusions, stimulated anew the flagging energies of the abiogenesists. The next champions of this latter cause who appear before us are Needham and Buffon; who, after due experimental investigation, declared themselves as convinced of the truth of the doctrine of abiogenesis. The experiments of Needham, made in 1745, were conducted after the same method as those of Redi, but, at the same time, they more nearly and fully approach the details of the modern experimentalist.

The efforts of Needham were accordingly directed to the investigation of the conditions under which *Infusoria* and allied forms could be produced and propagated. If the *Infusoria* appear in infusions as the result of the development of germs or ova, these latter, he concluded, must be present in the infusion, or be borne by the atmosphere. And, therefore, if measures were taken to destroy the vitality of these germs or ova—the conditions of the

infusion remaining the same—no *Infusoria* should, after this treatment, appear in the infusion, and the biogenetic doctrine would accordingly be proved correct. But if, on the contrary, after this mode of investigating the subject, the animalcules were still found to be present in the infusion, then the decision would necessarily be in favour of the doctrine of abiogenesis.

Needham, considering that in a high degree of temperature the conditions necessary for the destruction of the germs were to be found, carefully boiled his infusion, and, after sealing it, again subjected it to the influence of a high degree of temperature. On opening his flasks after they had been allowed to cool, Needham found the infusion, notwithstanding its having been boiled, to teem with *Infusorial* and animalcular life. And he therefore concluded that the organisms must have been produced spontaneously from the fluid, or from the materials contained therein; since he firmly believed in the destruction by the heat of all living germs or organisms which the infusion, previously to its being boiled, might have contained. He therefore, after repeating his experiments, and with the same result, declared his firm belief in the truth of "abiogenesis."

At the same time, Buffon's theory of the production of life from "organic molecules" was promulgated chiefly as a result of the conclusions arrived at by Needham. This latter hypothesis, founded on and implying a modified belief in the doctrine of "abiogenesis," maintained that the essentially vital or life-giving properties were located in indestructible particles or "molecules," each of which had a vitality or life peculiarly its own. Buffon maintained that the body of every living organism, of whatever kind or grade, was merely a temporary aggregation of such "molecular" particles, which, liberated by the death of the organism, are once more free to enter into the combination and formation of another, and, it may be, an entirely different form. It is somewhat remarkable to find, ever and anon, the materials and ideas of an almost forgotten theory brought to light, and made to do duty,

under a fresh garb, in the establishment of a new hypothesis. There thus exists between certain recent notions of "molecules" and the ideas of Buffon a close and intimate relation, although the more modern ideas regarding them are different from the opinions of the French zoologist. The same material, however, does duty as the basis of all the "molecular" hypotheses which now and of old have been constructed and advocated.

Once more, therefore, the struggle and controversy seems to turn in favour of abiogenesis. But a new champion of the opposing doctrine soon enters the lists, and quickly throws the balance towards the biogenetic side. The Abbé Spallanzani, directing attention to the experiments of Needham, showed, in 1765, that the presence of living organisms in Needham's boiled infusions was due to want of care and skill in the method of closing his flasks. And Spallanzani demonstrated the want of care and erroneous conclusions of Needham by preparing infusions of similar kind, by closing them after an improved and different method, and by continuing the process of boiling till a higher rate of temperature than that reached by Needham was attained. The infusions of Spallanzani, so treated, were found on microscopical examination to exhibit no signs of vitality. Hence the exertions of the Abbé turned the tide in favour of biogenesis, and resulted in the foundation of his "universal germ theory," the essential feature of which was the recognition of germs borne by the atmosphere as the origin of all the forms of infusorial life.

The controversy at this point, however, assumed a new and entirely different aspect to that which had formerly characterised it. The birth of an improved chemical science opened up a *chemical* aspect which had formerly been unknown; and it was now assumed or suggested that the non-development of life in the infusions of Spallanzani might possibly be due to the influence of chemical changes induced by the process of boiling. And similarly followed the assertion that fermentation and putrefaction were changes of a chemical nature, and were not caused by the

presence of certain living and organic forms. The former of these views with regard to fermentation was held in modern times by the late Baron Liebig, whilst the latter opinion is as strenuously advocated by Pasteur.

Schulze and Schwann, in 1837, disposed of the chemical objections to Spallanzani's experiments, by allowing only air filtered through strong chemical solvents, such as sulphuric acid and caustic potash, or air passed through red hot tubes, to reach the infusion. The oxygen of the air, which was considered so necessary to the development of life, and which in Spallanzani's experiments was thought to be affected by the process of boiling, was accordingly allowed to reach the infusion. The chemical uniformity of the air was thus preserved intact, but at the same time it was deprived of the organic germs, which Spallanzani had maintained were the cause of the development of life in the infusion; and after being so treated, the infusions displayed no signs of vitality. And Schrœder and Dutsch, in 1854, substituting simple cotton-wool for the chemical solvents of Schulze and Schwann, showed that air filtered through such a medium was incapable of developing living organisms.

The investigation and discovery, by De la Tour, of the "yeast plant" (Fig. 20, *n*) as the cause of fermentation, chiefly occasioned the hot controversy already referred to, as to the nature of the fermentative and putrefactive processes; a controversy which, however, was satisfactorily settled in favour of De la Tour's view and discovery, by the experiments of Helmholtz, who proved, in the years 1843-44, that the mere separation by a thin membrane, of a putrescible fluid from one which was actually undergoing the process of fermentation and putrefaction, was sufficient to prevent the extension of the process to the former portion of the liquid. And in this way, he demonstrated, that if the cause of fermentation were purely chemical, there was no reason why the former fluid should not exhibit the same series of actions and phenomena as the latter and already fermenting fluid, since the purely

chemical conditions were the same in both. This experiment, therefore, showed that in all probability the cause of fermentation lay in the peculiar phenomena accompanying the development of living organisms within a fluid fit for their propagation; and the analogy between the development of such organisms and the production of *Infusoria* and allied forms in an infusion is at once apparent. Hence, the present stage of the controversy resulted in the demonstration, that the essential *materies* of fermentation, and in all probability of that necessary for the development of infusorial life also, existed in a state which was most nearly "particulate;" that is, consisting of minute "particles" of organic matter; which particles, like seeds in a fit and appropriate soil, were developed in the infusions into certain adult and specific forms.

The progress of the doctrine of biogenesis was thus exceptionally rapid and brilliant, and up to the present time its career has been no less striking. M. Pasteur's researches (1862) into the production of living organisms in infusions, and his demonstration of the "particulate" and specific nature of the germs or particles which give origin to forms of life in such media as infusions, and also within the bodies of higher animals and plants, are to be regarded as exemplifying some of the most important contributions to the support and establishment of the biogenetic doctrine. Whilst latterly Professor Tyndall has shown us that the existence of such particles in immense quantities in the ordinary atmosphere, is no longer a matter merely of conjecture, but one of absolute certainty and proof.

In the present day, therefore, the rival doctrines still oppose one another as of yore. And whilst the doctrine of biogenesis has been thus advancing towards complete demonstration, the interests of abiogenesis, and more especially during latter years, have not been neglected by ardent supporters. The record of progress in the demonstration of abiogenesis as a doctrine worthy of support has not, it is true, been so brilliant as that of the opposing theory; but the doctrine has not lacked

ıle advocates, who fail to see in the "germ theory" in allied hypotheses, a sufficiently reasonable explanaon of the occurrence and development, under certain rcumstances, of the lower forms of life.

The experiments of abiogenesists have generally been nducted with a view to show that, notwithstanding ie presence of conditions—such as those of great and ng-continued heat—unsuited, and otherwise considered tal to the existence and development of living or ganic germs, living organisms may still be found to be eveloped in infusions of organic matter. And these ganisms, they maintain, originate *de novo* from the moleıles of the contained fluid or substance; an assumption ıntamount to the belief that vitality can be created, or ıay spring into existence independently, and without ıe pre-existence of vitality or of living forms.

Thus the issue between the biogenesist and abiogenesist arrows itself to the belief, on one side, that the organic erms and particles are capable of withstanding a much reater temperature than is generally supposed or adıitted; whilst on the other side it assumes the phase of n opinion against the possession of such powers by rganic germs, or primarily against the specific nature nd universal existence of germs. And in conjunction ith these two points a third must be included, that of a elief in the "spontaneous" origin of living forms, through rocesses which may be deemed physical or chemical, or hysico-chemical in nature.

For and against these various points much evidence ıas been brought to bear. The most important contriıutions to the side and opinions of abiogenesists which f late years have appeared, are those of M. Pouchet and Dr. H. Charlton Bastian. M. Pouchet may be ranked ımongst the foremost pioneers of abiogenesis; and his laborate experiments have been chiefly directed to the efutation of those of Pasteur. Pouchet seems to incline o the belief that the organisms developed in infusions erive their characteristics from the particular fluids in which they are produced; a fact in part explicable to the

biogenesist, by the supposition that certain germs or organisms may flourish best in particular media. Dr. Bastian, in his recent work, entitled the "Beginnings of Life," seeks to show that the doctrine of abiogenesis holds a more philosophical status than that of biogenesis. The experiments detailed in this work are many of them of the most complicated and novel description; and whilst it is permissible to offer a few general observations on these and allied experiments, and also on the conclusions deduced therefrom, it must also be borne in mind that further research is required before perfect confirmation or contradiction of Dr. Bastian's views can be affirmed. The battle in the present day between abiogenesis and biogenesis is therefore one of the most keenly-contested which the history of any science has ever witnessed. Not only have we the highest authorities in biology ranked on either side, but the most complicated apparatus is now called into requisition by both parties. And thus the warfare is waged, with the circle ever narrowing itself; each step in the sequence of proof and demonstration being as hotly contested as if all the issues of biology and the kindred sciences were dependent upon the result of the battle.

The experiments of Dr. Bastian were conducted according to the method we have already pointed out. Infusions of organic matter were subjected in flasks to great and continued heat; the flasks were then hermetically sealed, and again subjected to a continuance of a high rate of temperature; and, after being allowed to stand for a longer or shorter period, the contained infusions were examined, with the very general result of finding living organisms developed therein. And such results Dr. Bastian has obtained even from solutions or infusions of *inorganic* nature—such as solutions of phosphate of soda, or of ammonia, and also from solutions of tartar emetic; this latter condition, that of a purely *inorganic* solution, being, so far as we are aware, of an entirely novel kind in the history of experimental research into the phenomena of biogenesis. Then, also, Dr. Bastian

has found that if infusions be of a sufficient strength, and of a highly fermentable kind, infusorial life is developed "*in vacuo*." And following up the same line of observation and experiment as that pursued by Dr. Bastian, we find Dr. Burdon Sanderson asserting that "liquids which contain no particle distinguishable under the highest powers of the microscope, can often be proved to possess the property of evolving microzyms (bacteria, etc.) after being boiled in sealed flasks without contact with external media."

The chief considerations which militate against the validity of the abiogenetic doctrine in general, and against that of the experiments from the results of which it would seem to derive a large measure of support, appear to consist primarily, and from *a priori* reasoning, in the fact that the conditions under which the development of Infusoria is expected and alleged to take place are thoroughly opposed to the exhibition or development of life. An inorganic solution, for example, presents us with a condition which, primarily, we would consider to be wholly unfavourable and unsuited to the exhibition and development of any living forms whatsoever; even allowing that they were capable of being produced by molecular combination, under physical conditions, or in any other way consistent with abiogenetic belief. The very occurrence of organisms in such an infusion, therefore, militates against the theory supported by Dr. Bastian, since the mere conditions for the development of life required by the physicist himself, are wanting in such a case.

Or, on the other hand, admitting the suitability of the preliminary conditions in the infusion, it might reasonably be doubted if the exceedingly high and continued rate of temperature to which the infusions were subjected, can be compatible with the development of living beings: yet we are informed that the development of life was as great in the infusion so treated as in one which had not been subjected to heat at all. The appearance of living organisms to such an extent, and under such conditions, would therefore seem to afford grounds for the belief in

the possession by the infusorial germs of greater powers of resistance to rigorous conditions, than, from previous experience, could have been conceived.

The actual existence of organic germs in the atmosphere, and in fluids of all kinds, has now been placed beyond the possibility of doubt. Whether the doctrine of abiogenesis and of the "spontaneous" origin of living forms be proved true or not, the fact that the atmosphere is the medium for the conveyance of vast quantities of organic germs, is insusceptible of controversion or of modification in any way. And the unavoidable admission of this fact constitutes a certain and significant argument of primary importance in favour of the ordinary and "biogenetic" development of these germs into infusorial and other forms of life. The abiogenesist, in the face of this fact, is placed in the position not only of an opponent to the belief in the actual existence of organic germs, but also to the idea of the connection between such germs and the lower forms of life; and to the consequent production of the latter by a process of ordinary development, in infusions of organic or even of inorganic material.

In connection with this latter point—namely, that of the connection between the forms of life found in infusions, and the organic germs of the atmosphere and fluids—it may be mentioned that Professor Lister has lately demonstrated, in the clearest possible manner, these important relations. This ingenious experimenter has thus shown that many of the organisms declared by abiogenesists to be produced by "spontaneous generation," are in reality the early or embryonic forms of certain fungi, which Mr. Lister has had the satisfaction of developing from germs; and these fungi were traced throughout their entire cycle of development. A fungus appearing in an organic solution on exposure to the atmosphere, was thus observed to produce "spores," which, after separation, gave rise to "young plants like the parents;" and other "spores," of precisely similar kind and origin, were seen to multiply by budding like

the Yeast plant or *Torula* (Fig. 20, *n*). The recognition of the transitional nature of the "spores," and of these alternating phases of development, thus supplies the connecting links between the organisms found in infusions and the germs from which they originate.

Mr. Lister has also observed the presence of slender filaments, which "were seen to break up into bacteria;" whilst the filaments themselves were noticed to be produced from spores, "indistinguishable from those of the fungus." These new and startling facts with reference to the origin of Bacteria (Fig. 29), and the knowledge that certain forms of life found in infusions actually represent stages in the life-circle of a fungus, place the controversy on an entirely new footing, and, at the same time, advance in an important degree the interests of "biogenesis."

A further and opposing consideration to the doctrine of abiogenesis, and one to be taken in consideration with the preceding remarks, is found in the fact that the lower forms of life, and presumedly their germs also, are capable of withstanding a long continuance of a very high rate of temperature. Hence, where the abiogenesist obtains a *positive* result in his treatment of an infusion—namely, that of the presence of infusoria, etc.—the biogenesist can assert his belief, susceptible of abundant demonstration, that a high rate of temperature is not inconsistent with the development of infusorial life from germs or spores, which are thus of a semi-indestructible nature. If, therefore, we are offered the choice of believing, on the one hand, that the organisms developed in a fluid subjected to such rigorous conditions as those we have described, spring from germs contained in the fluid, but which possess the power of resisting a very high rate of temperature; or, on the other hand, that the contained organisms are produced from a combination of the inorganic constituents of the infusion, and without the pre-existence of vitality, one can hardly think that the cautious discernment of a logical mind will hesitate in its choice of the former belief as that most

consistent with the ordinary experience of life, and best in accordance with the dictates of scientific knowledge and research.

The remaining and final considerations, which may be enforced in concluding the present subject, have reference, firstly, to the *nature* and subsequent history of the organisms developed in the infusions of Bastian and other experimenters; and, secondly, to *conditions of life* and vitality in even high forms of animal life, which bear an analogous relation to those conditions which we believe the microscopic germs of the lower forms of existence to present.

The organisms found by Dr. Bastian and others in prepared infusions were chiefly of a vegetable nature; the animal forms being limited to those of the lowest grade, many of which are hardly distinguishable from true plant-organisms. We thus observe the remarkable and noticeable absence of the higher and *Infusorial* forms which appear in such abundance in ordinary organic infusions. The forms of life found present in the rigorously treated infusions are therefore almost entirely of a vegetative kind; and, as such, may be regarded as presenting us with a lower type of vitality than truly animal forms. Consistently, then, with this lower vitality, we may presume their greater indifference to the conditions in which the infusions were placed; and hence the greater chance of such organisms being preserved, whilst the more highly organised forms would be destroyed.

Regarding the subsequent history of the forms assumed to be "spontaneously" produced in infusions, it is a fact worthy of note that they are observed to reproduce themselves after the ordinary modes of reproduction, and through the ordinary processes of development. These infusorial forms thus reproduce their like in exactly the same manner as when they occur in a natural state. And the mere occurrence in these forms of thoroughly normal reproductive processes, affords an argument of weight against the supposition of their "spontaneous" production by any of the modes included under the

doctrine of abiogenesis; whilst it also tends to impress more firmly upon us the uniformity of natural actions and laws.

We thus never witness in the after-history of these infusorial forms the occurrence of any abnormal or unusual processes of reproduction. The irruption into the circle of continuous and transmitted vitality does not seem to be repeated or again evinced in the subsequent history of these organisms. Nor can abiogenesis afford any explanation why organisms supposed to be thus spontaneously thrown into the world of being, should be capable of reproducing their like after ordinary and normal methods. And whilst the occurrence in these forms of the ordinary reproductive processes thus serves as an argument against their "spontaneous" production, the fact also goes to support the opposing doctrine of "biogenesis," in that it argues for the "cyclical" nature of the great vital processes, and for the invariable repetition, in the life-history of an organism, of the process by which itself was produced.

Finally, when we consider that in animal forms of an organisation so high as that of the *Rotifera* or "wheel-animalcules" (Fig. 3), we find a most remarkable exhibition of "dormant" or "potential vitality," our ideas of the conditions under which life and the vital force may be preserved and manifested assume an extended character, by aid of which we may draw several highly important conclusions with reference to the subject before us.

We have already remarked, in considering the nature of "potential vitality" (Chapter II.), that the *Rotifera* may be dried up from the pools by the heat of the summer sun, and in this mummified condition may be blown about as mere dust-specks for a considerable period, until the addition of a little moisture once more places them in possession of all their pristine and original vital powers.

The *Rotifera* which thus possess so wonderful a vitality, it must be borne in mind, are very far above the *Infusorian* animalcules in organisation; and we must further note that

it is not the mere eggs or germs which are thus subjected to so rigorous conditions, but the adult and mature Rotifers, in all their structural perfection and functional activity. And if the vital energies of creatures ranking so high in the scale of being, be thus capable of withstanding the influence of conditions so much at variance with the ordinary laws of vitality, we cannot, after such considerations, regard the exhibition of potential vitality on the part of the mere germs of much more lowly-organised forms, as of so unusual or extraordinary a kind. The experimental conditions already referred to, when considered relatively to the organisation of the *Confervoid* spore or germ of the lower animal organism, are not more rigorous than those to which the high organisation of the adult Rotifer is subjected.

A belief in the doctrine of Biogenesis, and in the invariable transmission of vitality, is thus shown to be of a decidedly more philosophical nature than that in the opposite theory of Abiogenesis ; involving, as does the acceptation of the latter doctrine, the assumption of actions and conditions unwarranted by the general teachings of a uniform biology, and especially by the ascertained laws under which vital force and living material are respectively exhibited and conserved.

CHAPTER XIV.

ıtribution -- Nature of the Subject -- Distribution in "Space and in "Time" — "Geographical" Distribution: its Division and Aspects—"Zoological Provinces"—Conditions affecting the Distribution of Forms in Space—Law of "Geographical Succession" — Homomorphism and Distribution—"Bathymetrical" Distribution — Deep-sea Life—Forbes' "Zones" of Marine Life—History and Progress of Deep-sea Exploration — Conditions of Life in the Depths of the Sea—Influence of Pressure -- Light —Temperature --Food-supply, etc.— Distribution in Time—General Considerations —Fossils— Life-Epochs —Imperfection of the Geological Record—Conclusion.

HE last or *Distributional* aspect of biological science as reference to the conditions under which the living rganism now exists in the world, and to those under which it may have existed in time past. We have lready seen that our examination of the structural and unctional relations of a living being places us in possession of full information regarding the organism, both in ts young state and in its adult form. But if our survey of the organism is to be complete in the true sense of the term, we have in addition to these points to investigate the relations which the living being bears to the world or medium in which it exists. To such relations, as distinguished from those elicited by the morphological or physiological survey of the being, the term "external" or "objective" relations is not unfrequently applied.

The "distributional" or "objective" relations of living beings admit of being studied from a twofold yet connected aspect. We may firstly direct our attention to the conditions in which the organism exists in the world around us; in what districts or "areas" it is found, and from what localities it may be invariably absent. This first aspect has therefore reference to the "geography"

of living forms; to their "geographical distribution," or, as it is occasionally termed, their "distribution in *space*."

The present history of an organism or series of organisms has generally and inseparably bound up with it the history or record of a past. This latter or past history has reference to the conditions under which the organism or series was represented in certain anterior or past epochs of our world's history, which the researches of the geologist and palæontologist have led us to recognise as possessing a definite existence. To this latter and second aspect of distributional science the names of "geological distribution," or "distribution in *time*," have accordingly been given.

These two aspects of our present subject, it is almost needless to say, are related to each other in the most intimate manner. The circumstances and facts elicited by a study of the one aspect or section, must usually be taken in connection with the generalisations of the other. The distribution of a form in the present may vary greatly, or, on the contrary, may vary but little, from the conditions under which it existed in the past; but in either case the two aspects will generally be found to be mutually explanatory, and in some cases the aid of the one is absolutely necessary to the proper understanding of the other.

The advice of Professor Greene with regard to the study of distribution, "to separate the facts of the science from the various theories which have been devised to explain them," is, I think, an exceedingly wise and useful caution in these speculative days. Since the biological student will not in any case extend his knowledge, or wander very far out of the more beaten tracks, without finding that a special theory has in very many instances been made and adjusted to the "facts of the science," without the slightest regard to the primary conditions or circumstances from which the facts take origin. Thus, as we have before had occasion to remark, and to select a single example, the doctrine of "special creation"

assumes the existence of special or "specific" centres of creation and distribution for the various species of living forms; and that their subsequent distribution radiated from these central points to a greater or less extent, and until it was checked and limited by natural barriers or conditions. Such a theory necessarily involves stated notions as to the distribution and subsequent modification of living forms. And other hypotheses similarly profess to explain the probable causes of distributional variations on grounds consistent enough with the facts as they stand, but which exhibit many flaws and deficiencies when subjected to a careful scrutiny and analysis.

The terms "flora" and "fauna" are respectively used to conveniently and shortly express the vegetable and animal population of a district, zone, or country; and concerning the aspects of the "Geographical" distribution of living forms, to which, in the first place, we may conveniently turn our attention, we have to notice the division of this subject into three sections. Thus we may firstly investigate the relations of the organism to the "medium" in which it lives. The conditions of existence on land, in air, or under water, and the consequent adaptations for that existence, may thus be considered under this first head. Then, secondly, we may direct attention to the "lateral" or "surface" distribution of animal forms; that is, to the purely "geographical" aspect of the subject. In this way we may take cognisance of the extent of surface or of the "area" over which the distribution of a form may extend; or we may note the limits by which its distribution is bounded or confined. And lastly, we may investigate the "vertical" or "bathymetrical" distribution of living organisms; this latter aspect having reference to the distribution of forms relatively to the "depths" or "vertical surfaces" amid which they may be placed. The investigation of the depths of the sea thus falls under the consideration of this third head or aspect of the present subject.

The entire subject of distribution, it is to be noticed, is one which is at present in a somewhat chrysalis-like

state; the rapid extension of our information and ideas bidding fair to place this department of biological science on a footing wholly and entirely different from that in which it now exists, and to evolve new conceptions of the conditions of life, particularly in the lowest organisms. The present sketch can therefore embrace only the most general of considerations; and even these must be made with some reservation in prospect of the new facts which the progress of current research is almost daily bringing to light.

The naturalist, in considering the distribution "in space" of living forms, finds it convenient to divide the surface of the globe into a number of definite "areas" or "provinces," known generally as "zoological" or "botanical provinces." These "provinces" together make up the distributional world, just as continents collectively constitute the world in a purely geographical sense; but concerning the exact limits and extent of these individual provinces naturalists are by no means agreed.

The various "species" of forms which compose the organic whole, vary widely in their general distribution, as also in the more special limits by which the distribution of each individual or single species is bounded or confined. In the same way that a general similarity of appearance serves to reconcile and unite together the various "species" found in a "genus," so the various forms included in a distributional "province" are generally united to each other by certain relations of a more or less intimate and definite kind. These relations, it must however be borne in mind, are not *necessarily* of a structural character, or dependent upon the presence of a true specific relationship between the forms which inhabit the province. Although, therefore, closely-allied "species" may be situated within the same area or portion of an "area," the intimate nature of their distributional relations does not necessarily indicate any other association than that which may be said to depend or follow upon an exposure to surrounding and similar conditions.

The conditions and circumstances which regulate the

"lateral" or surface distribution of living beings, and from which extensions or limitations of distribution have taken origin, may be regarded as chiefly dependent on physical causes, which affect to a greater or less degree the life and habits of the forms included within a given area. The influence of physical conditions upon the organisms inhabiting the globe, has formed the basis of not a few of the theories relative to the specific origin of, and to the differences between, the forms that people the universe. And although we may not assume that these conditions are capable of affecting the living organism to the extent demanded and advocated by such theories, there can be no doubt of the very definite influence which surrounding conditions exert upon a living being placed and situated in their midst.

The study of physical geography aids us in framing correct generalisations with regard to the geographical distribution of living forms; and serves at the same time to impress upon us the due influence upon animal and plant life of the conformation of the earth's surface, and of the conditions which follow or depend upon any particular disposition of physical agencies.

Thus the existence of a mountain-chain may produce visible and apparent effects in the distributional aspects of a zone or territory. The intervention of a chain of mountains may divide closely-allied, or even a single species, and necessitate their classification in distinct and separate "zoological provinces." And the same condition which prevents the union of such species may similarly tend to limit the migratory or spreading tendencies assumed to be inherent in most forms. The separation of tracts or lands by rivers, seas, or oceans, has a corresponding and definite influence in the division of species or groups, and in the localisation of forms.

Other conditions, however, must also be included in the list of physical agencies affecting the distribution of animals or plants. The influence of food and climate tends to alter the conditions of life and habitat of forms, just as we have observed these agencies to be instru-

mental in changing "specific" into "varietal" characters. The food-supply of animals has thus a most powerful influence upon their distribution. The aggregation of forms where food is plentiful, and their absence from those districts where food is scarce, constitute the most obvious of generalisations and laws induced by the state of the food-supply.

And similarly with climate; the influence of this latter condition being even more visible and ascertained than that of the food-supply. The influence of a rigorous climate, as tending to disperse animal forms from a given area, or that of a genial climate in fostering their aggregation, will be readily estimated; whilst to the alteration and succession of the seasons, inducing a colder climate or the reverse, is due the temporary change of province or area, which, in birds, we familiarly term "migration."

The relations of distribution in "space" to distribution in "time," have an intimate bearing on the comparative duration of "species" and groups of forms in a given locality or "area," and also on the relative stability of a "zoological province." We may thus find the constitution and limits of a zoological province to remain in the present, much, or exactly the same, as they appear to have been in the past; the *specific* nature of the included forms, however, having been materially altered and changed. In other words, a zoological province may be occupied in the present day by species and genera different from, but still allied to, those which inhabited it in the past.

These conditions and phenomena are included to form a law, known as that of the "geographical succession of organic forms," which, according to Owen, is embodied in the expression, "that with extinct as with existing Mammalia, particular forms were assigned to particular provinces; and that the same forms were restricted to the same provinces at a former geological period as they are at the present day." The "former geological period" here referred to, it must however be remarked, was "the more recent tertiary one."

At a very recent period, geologically speaking, we may thus observe that the fauna of a particular region exhibited certain peculiar and distinctive characters. And, as expressed by the "law of organic succession," these special characteristics of the fauna may, in the present day, still be found within the same province, but represented and perpetuated by entirely new and different *species* of animals. The characters peculiar to the whole fauna still remain, but the representative *species* are widely different from the species of the past.

Thus, to quote the familiar example of the distribution and relations of the South American *Edentata*, we observe the characteristics of the extinct and gigantic Sloths, and of the armour-plated *Glyptodon*, to be embodied and perpetuated in the modern species of Sloths, and in the existing Armadillos respectively. And similarly with the monkeys, llamas, tapirs, and peccaries of South America. The fossil "species" of these latter forms differ from existing species, but the distinctive peculiarities of each "group" are perpetuated in the living representatives. The fossil monkeys were thus of the *Platyrhine* kind, just as the living *Quadrumana* of South America belong exclusively to that group. And the extinct tapirs, llamas, and peccaries, although *specifically* distinct from their living representatives, nevertheless presented the same characters by which these forms, as distinct "groups," are now recognised.

The extinct mammals of Australia were also of a kind similar to those which now render that region so peculiar among the zoological provinces of the world. The recent deposits of Australia give evidence of as great an abundance of *Marsupial* life in the past, as now exists in that region. These extinct *Marsupials* were of different *species* from existing kangaroos, etc., but they formed in their period a no less distinctive fauna than that which characterises the Australia of to-day.

And the examples of "organic succession" thus given, might be repeated with reference to almost every region of the globe in which palæontological research has made even

limited progress. It is, however, important to bear in mind the observation already noticed—namely, that this law of "geographical succession" is applicable only to the later tertiary period of geology; and that it thus deals with superficial formations and with comparatively recent times. The zoological provinces of the present day are, however, thus proved to be generally of earlier date than the species or forms by which they are populated.

In connection with the "surface" distribution of animal forms, we may lastly notice the presence of certain features of correspondence between the fauna of widely-separated areas or provinces, whereby certain representative forms of one area are represented in another and widely removed province by analogous species, which latter, apart from all structural affinities, appear to fill the same place in their particular province as their neighbours in the other area. "Thus," to use the words of Professor Phillips, "the Platyrhine Monkeys of the new world are balanced by the Catarhine Quadrumana of the old world; the Feline races of Asia and Africa, the Lion and Leopard, are copied, so to speak, by the Puma and Jaguar of tropical America; the Tapir of Mexico mimics the congeneric animal of Sumatra; the Sloth, Armadillo, and Myrmecophaga of Brazil, find relatives in the Manis and Orycteropus of Asia and Africa."

And to these we might add the representation in South America by the llamas and alpacas, of the camels of Asia and Africa; or the balancing of the entire mammalia of other provinces by the single marsupial order of Australia. Whilst amongst birds, reptiles, fishes, and many invertebrate orders, many other examples of this distributional correspondence between forms might be found.

This subject has already been referred to in treating of Homomorphism, when we noticed the theories and views which had arisen from the fact of such widely-removed forms frequently exhibiting a striking resemblance to each other; and from the supposition that such a resemblance depended upon a common origin, upon the performance of similar functions, and upon the subjection

to like external conditions. These ingenious views cannot, however, be regarded as wholly satisfactory, or even as explanatory of facts as they stand; and, as already pointed out, the views of Forbes—who regarded special creations in similar areas as serving to explain these "homomorphic" resemblances—leave many points of the subject as inexplicable as before.

The consideration of the "vertical" or "bathymetrical" distribution of living forms exemplifies in a striking manner the sweeping changes, which even the limited progress of research has wrought in our ideas of the distribution of life throughout various areas or provinces. And the older belief in the limitation of the life-fields to certain depths, in the case of the marine "zones of distribution," has now been swept away by the better investigation of the deep-sea bed.

The researches and explorations of the late Professor Edward Forbes, chiefly led naturalists to classify marine forms, with reference to their "vertical" distribution, into five great classes or "zones." These "zones" or "bathymetrical areas" were arranged as follows:—

1*stly*. The "littoral" zone, extending between high and low water marks, and including forms which are not affected by a temporary withdrawal from their native element. The crustacea generally, and many mollusca, exemplify such forms.

2*dly*. The "circumlittoral" or "laminarian" zone, extending from low-water mark to a depth of fifteen fathoms.

3*dly*. The "median" or "coralline" zone, distinguished principally as the chief habitat and sphere of coral life, and which extended from fifteen to fifty fathoms.

4*thly*. The "Infra-median," or "Deep-sea Coral" zone, extending from fifty to one hundred fathoms; and,

5*thly*. The "Abyssal" zone, extending from one hundred to about three hundred fathoms, beyond which depths but few living forms were supposed to exist.

These ideas thus limited the distribution of life in the ocean to a depth of about 1800 feet, or even to a less extent; the depth of 300 fathoms constituting, according to Forbes, a kind of "zero" in the bathymetrical distribution of marine life. Or, to use Forbes' own words, when speaking of the "Deep-sea Coral Zone:"—"As we descend deeper and deeper in this region, its inhabitants become more and more modified, and fewer and fewer, indicating our approach towards an abyss where life is either extinguished, or exhibits but few sparks to mark its lingering presence."

Recent deep-sea dredging expeditions, in which the names of Drs. Wyville Thomson and Carpenter, and Mr. Gwyn Jeffreys, stand conspicuous, have, however, demonstrated the presence, in the very lowest sea-depths, not only of vast fields of animal life of a low type of existence, but have also brought to light, from enormous depths, creatures of a high type of organisation, such as Echinodermata, Crustaceans, Molluscs, and even Fishes. These and concomitant facts, which further and daily research is bringing to light, tend at once to revolutionise and alter all our previous ideas of "bathymetrical" distribution, and to render the generalisations of Professor Forbes altogether inadequate to correctly express the conditions of life among the oceanic fauna as a whole.

Prior to the announcement of Forbes' ideas in 1843, however, living forms of animal life had been obtained from a depth of nearly 1000 fathoms. These living forms consisted of several tube-dwelling worms, together with a large specimen of the "Medusa-head" Starfish (*Astrophyton linckii*). These organisms were found in the mud of the sounding-lead, and attached to the sounding-line of the Arctic Expedition of 1818, which was conducted by Sir John Ross. This incident constitutes the first undoubted and verified instance of animals of a comparatively high grade of organisation being obtained from a very great depth of sea.

Then, in 1855, the late Professor Bailey of the United States, published the fact that the fine ooze or mud of

the North Atlantic sea-bed consisted in greater part of minute *Foraminifera*, both in a living state and as dead or disintegrated organisms. These organisms were obtained from depths varying from 1000 to 2000 fathoms; and Professor Bailey gave it as his opinion that these *Foraminifera* were inhabitants of the upper strata of water, and that they had been conveyed to the lower depths by currents, or as the result of their death and disintegration. Ehrenberg, on the other hand, more correctly concluded that these *Foraminifera* were to be considered as deep-sea organisms in every sense of the term; and that they lived in the lowest depths of the ocean, and thus constituted vast fields of life in a region formerly thought to be entirely destitute of the presence of vitality.

The observations of Dr. Wallich in 1860, and the remarks of Professor Huxley on the ooze obtained in the soundings of 1857 for the route of an Atlantic cable, tended to confirm the supposition of Ehrenberg with regard to the habitat of the *Foraminifera*, and thus opened up a new era of thought with regard to the life of the sea-depths.

In the "Bulldog" Sounding Expedition, commanded by Sir Leopold M'Clintock, which was undertaken in 1860, with a view to determine the feasibility of a new route for an Atlantic cable, and which Dr. Wallich accompanied as naturalist, several "Brittle-stars" (*Ophiocomæ*) were brought up on the sounding-line from a bottom-depth of over 1200 fathoms. And the stomachs of these *Ophiocomæ* were found to contain *Globigerinæ*—those *Foraminifera* of which the oceanic ooze of the ocean beds is in greater part composed—this fact serving to show that these Brittle-stars normally existed at this great depth, and that the *Globigerinæ* of the sea-bed constituted their usual and ordinary food. The "Bulldog" expedition further procured various *Annelids*, some lower *Mollusca* (*Polyzoa*), and even *Crustaceans*,—all of which were obtained from depths which were formerly accounted absolutely unsuited for the growth and development of living organisms.

The results of subsequent and comparatively recent dredging expeditions, together with the progress of current research, have demonstrated the error of the ideas formerly entertained with regard to the vertical distribution of marine life; and have shown us that the depths of the sea constitute an entirely novel field for biological exploration, and one which is now being thoroughly worked and investigated under qualified guidance, and by the aid of efficient and improved apparatus.

Any system or tabulated scheme of the vertical or bathymetrical distribution of marine life, professing to meet the exigencies of our increasing knowledge, would have therefore to include the entire depth of the ocean, from the "littoral zone" to the lowest bed or sea-depth. Or, recognising the utility of the first four zones of Forbes, we should have to extend the limits of his fifth zone to include the depths from 300 fathoms to the bed of the ocean; the constitution and life of this latter area or zone presenting, in all probability, characters of a kind exceedingly varied from those which distinguish the fauna of the other and more superficial zones.

Without entering, in the present instance, into the details and classification of the forms which are ascertained to make up in part the population of the lower sea-depths, we may very briefly glance at the probable conditions under which life exists in these depths. These conditions of life have been chiefly included under the considerations relating to the pressure, light, temperature, and food-supply of the organisms which exist at such enormous depths in the ocean. A few words on each of these latter points will not be out of place in concluding our remarks on the aspects of geographical distribution.

The question of *Pressure*, as constituting a condition pre-eminently unfavourable to animal existence in great depths of sea, has, until recently, influenced discussions on the subject to a greater or less extent. It has, however, been pointed out, that in accordance with the most familiar of the laws of natural philosophy, the pressure upon the outer surface of an organism living in the

greatest depths of sea, would be perfectly counterbalanced by an equal pressure of water from within the organism. The law of the equal pressure of fluids in all directions, and its application to the case of these animal organisms, thus removes a stumblingblock which long impeded the correct appreciation of this important modification of what would otherwise appear to be a thoroughly unfavourable condition to the maintenance of life in the sea-depths. And although we know that at a depth of 2400 fathoms the pressure upon an animal organism must amount to about three tons on each square inch of its surface, yet the equal distribution of fluid pressure constitutes a perfect provision and natural safeguard against any deleterious effects. The condition of the lower organism without air-cavities of any kind, and under such circumstances, is thus maintained in perfect equilibrium, and has been compared in some degree, by Dr. Carpenter, to the similar and perfectly-balanced condition of land-animals, which exist under enormous atmospheric pressure, and under variations in that pressure, without experiencing any effects, or indeed without necessarily being aware of such pressure being at all exerted.

That this purely physical condition, therefore, is fulfilled in greater or less degree by marine forms, in whatever zone or depth they may reside, there can be no doubt. The law which applies to the surface-living form is also applicable to its deeper neighbour. The latter form, however, submits to more rigorous conditions than the surface-form, simply and in virtue of the greater pressure which exists and operates at a greater depth.

The absence of *Light* in the depths of the sea has, similarly to the consideration of pressure, proved a somewhat awkward fact to the supposition that the necessary conditions for vitality are or can be present at great oceanic depths. We have already referred to the importance of light as a subsidiary condition for the manifestation and maintenance of vitality and of vital functions. Yet the ascertained absence of light at but a very short distance from the surface of the ocean, does not

appear to affect the growth and development of many animals which pass their existence in moderate but entirely darkened depths. Nor does this absence of light appear to be attended, in the case of deep-sea organisms, with the results which we naturally expect to follow non-exposure to the solar rays. The coloration of certain forms, brought up from depths of from 500 to 600 fathoms in deep-sea dredging expeditions, was found to be as brilliant as that of their ordinary "littoral" or shore representatives (Carpenter.) The explanation of these anomalous circumstances, and the determination of the causes why absence of colour should follow non-exposure to light in one case, and not in another, have yet to be framed and suggested; but two thoughts or suggestions are admissible in the present state of our knowledge. We may thus either suppose that the vital functions may, from adaptative conditions, be carried on in these organisms in the absence of light; or, on the other hand, that special means may be afforded whereby the influence of the surrounding darkness may be counterbalanced or neutralised. And to these considerations we may not inappropriately add the third, of the possible adaptation of chemical laws and conditions which may influence the development of colour in these organisms, and under the special circumstances of their life, position, and habits.

Throughout the higher groups of the organic series the presence of light appears to be almost absolutely essential to the perfect performance of vital functions. Where we find forms of a high degree of organisation living in darkness, a general absence of colour, together with non-development or a rudimentary condition of the visual organs, are generally to be perceived. Yet, in the case of certain forms brought up by the dredge from enormous depths of sea, and which, from a careful consideration of their habits, appear to normally exist in the lowest depths of the ocean, the eyes appear as perfect in every way as those of nearly-related organisms living and existing in the light.

Such facts constitute most intricate and difficult points in the consideration of the conditions of life in the sea-depths, and more perfect knowledge is requisite and necessary before further attempts to account for or explain these anomalies can be warranted. But the consideration of such phenomena, and the solution of the difficulties which attend them, have not been neglected by naturalists and physiologists in the past.

Dr. Coldstream, in the *Cyclopædia of Anatomy and Physiology*, together with Ehrenberg, De Quatrefages, and others, have of old directed attention to the hypothesis or suggestion that the deep-sea forms may be capable of seeing by aid of the phosphorescent light which themselves or their neighbours are capable of producing. Thus Coldstream quotes the remark by Macculloch, from the *Edinburgh Encyclopædia*, that "in marine animals their luminousness may be 'a substitute for the light of the sun,' and may be the means of enabling them to discover one another, as well as their prey."

This hypothesis, which deserves mention if from no other consideration than its ingenious nature, has been repeatedly referred to and reproduced in discussions on the conditions of life in deep-sea or in ordinary marine organisms. Objections to this supposition have been founded on the fact that the power of producing this phosphorescent light is not possessed by all the forms inhabiting the sea-depths, nor by those dwelling in shallower but still darkened water; the surface of the sea, indeed, being the particular region or tract where the luminosity is most to be perceived. Then, also, it has been shown that forms which apparently would most benefit from the possession of this property are destitute of it; whilst other animals, the habits of which do not appear to necessitate such a provision, possess the phosphorescent property in fullest vigour.

These and allied considerations certainly militate against the validity of this supposition; although, from the nature of the case, and from the present state of our knowledge, we cannot satisfactorily either support or

reject a suggestion offered and propounded after a due consideration of facts as they stand.

The subject of *Temperature*, as affecting the conditions of life in deep-sea organisms, is not surrounded by such difficulties as beset the question and relations of light. The due observation and investigation, by aid of improved apparatus, of the temperature of the ocean at various depths, has led to the well-founded belief that the temperature of the sea is regulated by the distribution and direction of the currents which at all depths affect its mass. By the agency of these moving streams the degrees of heat and cold in the sea-depths are duly regulated ; and it has been found that the distribution of hot and cold areas in the ocean has a very important, if not the most important, effect in determining the range and distribution of life throughout the wide domain and depth of sea.

The ideas formerly entertained concerning the relative temperature of various sea-depths have been greatly modified, and in some cases completely superseded, by the results of recent investigations. And although the consideration of such a question belongs more properly to the department of physical geography, yet the recognition of the influence of temperature on the bathymetrical distribution of life may warrant us in briefly stating the conclusions to which late investigations have led.

Formerly it was believed that the temperature of the ocean at certain depths was of a permanent and stable character, and corresponded to about 4° C. The surface temperature, on the other hand, was believed to vary greatly under the influence of the heat of the sun, from the effect of currents and of winds, and from other causes. The results of recent investigations tend to show, as expressed by Professor Wyville Thomson, "that instead of there being a permanent deep layer of water at 4° C., the average temperature of the bottom of the deep sea in temperate and tropical regions is about 0° C., the freezing-point of fresh water ; and that there is a general surface movement of warm water, produced pro-

bably by a combination of various causes, from the equatorial regions towards the poles, and a slow under-current or rather indraught of cold water from the poles towards the equator."

In the conditions which affect the distribution of marine forms, therefore, we may assign to temperature the first place of importance. "The nature of the ground," to use Professor Thomson's words, "can have little to say to it, for on every line of coast, of any extent, almost every condition and every kind of sediment is usually represented."

Finally, the question of *Food-supply* has also been regarded as forming one of the knotty points in the consideration of the distribution and maintenance of deep-sea existence. The existence of a food-supply to the animal bears, as has already been shown, an important relation to the presence of light; since the plants necessary for the maintenance of animal-life require the presence of sunlight for the due operation of their vital chemistry. The absence in the sea-depths of any but a few of the lowest, and generally microscopic plant-organisms, forms, therefore, a notable feature in the consideration of the present subject; since, in the absence of the solar-beam, the higher plants cannot exist, and with them disappears the chief support and stay of animal existence.

From the contemplation of such a difficulty arose the suggestion that the lower animals in the sea-depths might assume the functions of plants, in that they might be conceived to be capable of availing themselves of the inorganic materials by which they were surrounded, and of elaborating from such matter a nutritive supply. This supposition, however, has been abandoned in favour of a second theory, which, whilst it offers a more feasible explanation of the mode in which the nutrition of these organisms may be provided for, is not wholly free from objections to its favourable reception. This latter idea maintains the existence, in the great quantity of organic matter held suspended in the water of the sea, of a

supply of nutrient material, sufficiently and physiologically adapted for the sustenance of these lower organisms.

The actual presence of such organic matter in great depths of sea has been fully demonstrated, and this material has been supposed to be derived from the "surface-life" of the ocean, and from marine vegetation, together with the matter derived from the disintegration of the dead bodies of organisms of every grade and kind. Such organic material, thus widely diffused throughout the water of the ocean, and consisting of "dilute protoplasm," is therefore believed to afford food for organisms, the resources of which, from habits or distribution, appear of the most feeble and contracted kind. And the theory, which thus accounts for the food-supply of these deep-sea forms, is generally known as that of the "Protozoic-absorption theory."

Whilst this hypothesis appears sufficiently tenable and worthy of belief, until the question be more thoroughly worked out, there are a few points which may be suggested as militating against the theory. Thus the question of the actual necessity for recognising a food-supply in this "decomposable organic material" may not inaptly be raised. We are familiar with very many organisms, from all classes of the animal kingdom, up to and including the fishes, which may be preserved in a living and healthy condition, and for an indefinite period, without being furnished with any solid nutrient material. And the supposition that these deep-sea organisms may, like other and higher forms, find in the microscopic organisms and particles which are contained in even the clearest water, a source of food-supply, somewhat invalidates the necessity for our looking beyond the ordinary medium and conditions in which they live for the presence of nutrient matter.

The respiration of deep-sea forms, and the renewal of the gases concerned in the aërating-processes, in the absence of plants, are effected under the most admirable conditions. "Surface-waters" were found to contain a large percentage of oxygen, and comparatively little

carbonic acid; whilst "bottom-waters" contain a large amount of carbonic acid, and comparatively little oxygen. These conditions, and the relative preponderance of these gases, depend upon the interchange of oxygen and carbonic acid which takes place in the functional life and respiratory processes of deep-sea forms; the carbonic acid emitted by the organisms being consequently in greater preponderance in the lower depths, whilst the renewed oxygen is present in greater quantity in the upper strata of water. The renewal of the oxygen, and disposal of the carbonic acid, is effected by the downward diffusion of the former and the upward diffusion of the latter gas. A second interchange between the gases of the atmosphere and the gases of the sea thus takes place at the surface of the ocean; and the diffusion and renewal of oxygen is amply provided for by the currents of air and ocean, which together ceaselessly agitate the sea-depths, and so provide for the due purification of the great mass of waters.

Lastly, the presence of diffused mud-particles throughout certain areas (*e.g.*, the deeper parts of the Mediterranean Sea) has been credited with causing an almost entire absence of life, and of thus affecting in an important degree the distribution of deep-sea organisms. But, as has been ably pointed out by M'Intosh, the consideration that very many animals — Molluscs, Annelids, together with Sponges, and other and lower forms of marine life — normally live and thrive in very muddy waters, presents an antagonistic aspect to this theory. Indeed, as has been pointed out, the muddy districts of "littoral" areas present a marked contrast in respect of their abundant life, to those districts where the water is clear and undisturbed. And even amongst the thickest chalk-ooze and putrid mud, many characteristic Molluscs and Annelids are found to flourish in all their vigour and beauty. Thus the conditions of presumed unfavourable aspect to the development of life in one case, become in another case, and unaccountably, a normal habitat for organisms of a higher grade of organisation.

But in conformity with the current progress of research, we may reasonably hesitate to express any decided or further opinion as to the tenability of theories or opinions which may be entertained with regard to the "bathymetrical" distribution and conditions of deep-sea life.

The subject of "Distribution in Time" admits, in the present instance, of only a few considerations, and these must be of the most general description; since the due appreciation of the facts and conclusions to be derived from a study of the palaeontological record is dependent to a very great extent upon a certain knowledge of geological science.

The "geological" distribution of living beings, in its fullest sense, thus implies, firstly, the investigation of the past history of our earth, with regard to the physical and other conditions under which the life of the past existed; secondly, the determination of the conditions under which the remains of animals and plants have become preserved to us in the rock-systems of our globe; and, thirdly, the examination of such "fossil" forms, and their comparison in the details of structure and function with the living forms now existent.

The department of science which deals with the relation and structure of living forms in the past is known as that of "Palaeontology;" and this branch of inquiry is in turn generally regarded as subsidiary in nature to the wider science of "Geology." The last-mentioned department thus investigates the past history of our earth, in the most extended sense in which such an investigation may be pursued.

The more general considerations which concern our present purpose and subject, are limited to those which may suitably preface a full and complete inquiry into the past history of living forms. We thus become aware, firstly, that many species of animals and plants have been represented in periods of our earth's history anterior to that in which we ourselves exist. These species are principally those of forms which have completely passed out of existence; in other words, they have become

"extinct," and are not identical with, or cannot be referred to, existing "species" of animals and plants. In addition to these "extinct" species, however, we find many species to be represented in the past which are still in existence.

These forms, belonging thus chiefly to extinct, but also to existent species, represent the past population of our globe, and with the more general relations of these organisms it is the province of our present subject to deal. They become known to us from the presence in the rock-formations which compose the "crust" of the earth, of the remains of animals and plants, preserved to us mostly in a petrified state, and known as "fossils," or as "fossil organisms."

A further examination of the distributional aspects of the past population of our globe, evinces the fact that it is possible to determine a certain arrangement and order in their existence; and, necessarily, in that of the rocks or material, in the substance of which they are imbedded. In this way we can trace the existence of certain definite epochs or periods in the history of our earth, and we can also determine that certain forms or groups of forms were characteristic of or represented the life of these periods. And the palæontologist is thus enabled to construct a tolerably correct scheme, exhibiting the development and distribution of life at various epochs in the past, and also to form some idea of the conditions under and through which that life was maintained.

It is, however, to be borne in mind as a primary and most important consideration, that whilst the majority of fossil organisms are "extinct," that is, have entirely passed out of existence; and whilst other fossil forms do not differ from existing species of animals and plants, there is, at the same time, no fossil form which cannot be referred to one or other of the great groups or subkingdoms into which both animal and plant series are divided. Then, in addition to the above fact, it must also be remembered that the extinction of a species is essentially and for ever final; in other words, when a

species has died or passed out of existence it never again appears.

The difference between the forms of the past and those of the present is therefore, one, comparatively speaking, of time and not of primary structural detail. And this difference in point of time and general resemblance is exhibited in a defined order; those fossil forms which occur in the first-formed or oldest rocks differing in greatest degree from those at present in existence; whilst the fossils occurring in the newer or last-formed rocks do not, as a rule, differ from existing species of animals and plants.

The successive and gradual formation of the "fossil-bearing" rock systems, which chiefly compose the crust of the globe, was thus accompanied by a correspondingly gradual development of life, this development beginning in order with the least highly-organised, and terminating with the production of the highest being. From the wider differences observable in the distribution and relations of the forms which existed in the past, palæontologists have classified the rock formations of the earth to form three great "epochs" or "life periods." In other words, these epochs are distinguished by the broad characters and wide relations of their contained fossils.

Each period, therefore, contains an assemblage or aggregation of fossil forms, which evince among themselves a certain relationship, chiefly and primarily represented by the time and circumstances of their formation and deposition to form fossil organisms. The fossils of each epoch, and, in many cases, of each rock formation, exhibit thus a comparative contemporaneity of development, and very often of extinction also; whilst the relationship between the fossils of a period or rock formation, so far as structural identity is concerned, may either be of a close description, or of a less intimate or entirely unconnected kind.

The first and oldest of the epochs or life-periods into which the entire series of rock-formations may be divided is known as the *Palæozoic*, *Primary*, or "Ancient-life"

period. This epoch includes the Laurentian; Cambrian; Silurian; Devonian or old Red Sandstone; Carboniferous (Coal-measures); and Permian systems of rock-formations. The fossil organisms included in this period exhibit, as a whole, very distinct and essential differences from existing species of animals and plants.

The *Mesozoic*, *Secondary*, or "Middle-life" period, forms the second epoch, and includes the Triassic, Oolitic, or Jurassic, and the Cretaceous or Chalk systems of rocks. This second epoch is characterised, like the Palæozoic period, by the specifically distinct nature of its included fossils from existing forms of life; a few exceptions to this rule, however, being found. The fossil flora and fauna of the Mesozoic period, however, approach more nearly than those of the Palæozoic epoch to existent species; and the term "Middle-life" period has been applied to this epoch, from the somewhat intermediate nature of its position between the older and newer periods.

The *Kainozoic*, *Tertiary*, or "New-life" period, forms the last of the life-epochs. It includes the more superficial rocks, beginning with the Eocene formations, and including the Miocene and Pliocene, and finally ending the entire series with the Pleistocene, and Post-Tertiary, or Recent deposits, which latter bring us to the formations of our own day. The contained fossils of the Kainozoic period evince, for the most part, a decided relationship with the existent species of animals and plants; many of the Kainozoic fossils being specifically identical with living forms, and the more recent or newest deposits exhibiting, as might be expected, the closest relationship to the existing flora and fauna.

The general considerations thus brought forward may suffice to give a broad or elementary idea of those more important generalisations with regard to geological distribution, which an acquaintance with the principles of geology and palæontology is alone calculated to perfectly convey. It may, however, be impressed, as a closing and final thought, that the geological or palæontological record is

by no means of a uniform, complete, or unbroken nature. The labours of the palæontologist have not resulted in the formation and demonstration of a continuous series of forms, leading us by gradual and successive stages from the era of creation to the present order of existence.

There exist, on the contrary, many and great gaps in the geological record; the ingenuity of theorists having been greatly exercised to account for, and fill up, the breaks in the palæontological chain. These deficiencies have resulted from various causes, with the operation of which the geologist is well acquainted. Two conditions may be enumerated as having tended to produce these imperfections. The first condition is included in the fact, that the destructive nature of many physical or geological actions has undoubtedly caused the obliteration of the fossil-remains of many rock-formations. And, secondly, the absence of many animal and plant forms, which, from surrounding circumstances, or from their habits, would not tend to become fossilised, has left the "record of the rocks" necessarily in an imperfect and interrupted condition. Without, therefore, expressing dogmatically that the progress of research will disclose no new facts, or result in the discovery of no further or more extended generalisations regarding life in the past, we may safely assume that the imperfections and deficiencies alluded to are of a thoroughly permanent nature; and are such, that no succeeding phases of knowledge can ever suffice to render the record of life in the past any the more perfect, or to enable us, with precision and certainty, to fill in all the missing pages in the history of our globe.

GLOSSARY.

G, *Greek derivatives.* L, *Latin derivatives.*

ACCRETION. (L. *ad*, to; *cresco*, I grow.) The process of growth in inorganic bodies, by which new particles of matter are placed on top of those already formed.

ACTINIA. (G. *aktis*, a ray.) A genus of Cœlenterata, represented by the Sea-anemone.

ACTINOZOA. (G. *aktis*; and *zoön*, an animal.) The higher of the two Cœlenterate classes, of which the Sea-anemone may be taken as the type.

AGAMIC. (G. *a*, without; *gamos*, marriage.) Applied to "asexual" forms of the reproductive process; so called because the sexes do not participate in the process. Used synonymously with the term "*Asexual.*"

ALGÆ. (L. *alga*, a seaweed.) The group of lower plants popularly known as and including the "Seaweeds."

ALLANTOIS. (G. *allas*, a sausage.) One of the three fœtal or embryonic sacs of the higher *Vertebrata*. The allantois principally subserves the respiratory function of the embryo.

AMNION. (G. *amnos*, a lamb.) The embryonic sac developed from the "serous" layer of the germ, within which the embryo is more immediately contained.

AMŒBA. (G. *amoibe*, a change.) A genus of *Protozoa*, characterised by the power of changing the form and shape of the body. Formerly known as the "*Proteus animalcule.*"

AMPHIBIA. (G. *amphi*, both; *bios*, life.) A class of *Vertebrata* exemplified by the Frogs and Newts, which possess respiratory organs (gills and lungs), suiting them for life either on land or in water.

ANARTHROPODA. (G. *a*, without; *arthron*, a joint; *pous*, a foot.) A subdivision of *Annulosa*, represented by Worms, etc., in which no jointed limbs exist.

ANDROGYNOUS. (G. *aner*, a man; *gune*, a woman.) Applied to organisms in which the two sexes are united in one individual. Used synonymously with *Hermaphrodite*.

ANNELIDA. (L. *annulus*, a ring.) A class of *Annulosa* represented by the Worms.

ANNULOIDA. (L. *annulus;* and *eidos*, form or resemblance.) A term applied to the sub-kingdom *Echinozoa*, from supposed affinities with the *Annulosa*.

ANNULOSA. (L. *annulus.*) A sub-kingdom of animals, characterised by the jointed or "ringed" nature of their bodies, and represented by Worms, Insects, Spiders, and Crustaceans.

ANTENNÆ. (L. *antenna*, the yard of a ship.) The "head" or "cephalic" appendages of many *Invertebrata*. Popularly denominated "feelers," from their being supposed to subserve the sense of touch.

ANUS. (L. *anus*, the vent.) The vent, or inferior termination of the alimentary tract.

ARACHNIDA. (G. *arachne*, a spider.) A class of *Annulosa*, represented by the Spiders, Mites, and Scorpions.

ARTHROPODA. (G. *arthron*, a joint; *poda*, feet.) The higher subdivision of the *Annulosa*, in which jointed limbs are present.

ARTICULATA. (L. *articulus*, a little joint.) A term used synonymously with *Annulosa*.

ASCIDIA. (G. *askos*, a bag or bottle.) The scientific name of the "Sea Squirts," so called from their resemblance to a bottle or jar.

ASEXUAL. (L. *a*, without; *sexus*, sex.) *See* AGAMIC.

ASSIMILATION. (L. *ad*, to; *similis*, like.) The process by means of which living beings convert matter or food derived from the outer world into the substances of which their tissues and organs are composed. Assimilation in this way is a wider term for the process of "nutrition."

AVES. (L. *avis*, a bird.) A class of *Vertebrata*, including the Birds.

BACTERIUM. (Plural, *Bacteria.*) (G. *bakterion*, a staff or rod.) Applied to minute rod-like organisms, of vegetable nature, which occur in infusions.

BALANUS. (G. *balanos*, an acorn.) The scientific name of the "Sea-acorns"—a group of the *Crustacea*.

BILATERAL. (L. *bis*, two; *latus*, a side.) Possessing two equal or symmetrical sides.

BIOLOGY. (G. *bios*, life; *logos*, a discourse.) The science of life or of living beings. Now applied to include the two sciences of zoology and botany; or used as a subdivision of the wider science of "Natural History."

BIOPLASM. (G. *bios; plasso*, I form or mould.) Dr. Beale's term for "sarcode," "protoplasm," or the primordial matter, of which the bodies of living beings are composed.

BLASTODERM. (G. *blastos*, a sprout; *derma*, skin.) The "germinal membrane" of fecundated animal ova or eggs, from the ulterior development of which the embryonic form is eventually produced.

BOTANY. (G. *botane*, a plant.) The division of Biological or Natural History Science which investigates the structure and functions of plants.

BRANCHIA. (G. *bragchia*, gills.) A "gill" or breathing organ, fitted for breathing the air contained in water. The respiratory organ of aquatic forms.

BRYOZOA. *See* POLYZOA.

CALCAREOUS. (L. *calx*, lime.) Composed of lime.

CEPHALIC. (G. *kephale*, the head.) Belonging or appertaining to the head.

CHELÆ. (G. *chele*, a claw.) Invertebrate limbs provided with pincer-like appendages. The "nipping-claws" seen in lobsters crabs, scorpions, etc.

CHITINOUS. (G. *chiton*, a tunic.) Of horny texture. Applied to those structures in which "chitine," a substance allied to "horn," is found.

CHLOROPHYLL. (G. *chloros*, green; *phullon*, a leaf.) The green colouring material found typically in plants, but also in many animal forms.

CHORDA DORSALIS. *See* NOTOCHORD.

CHORION. (G. *chorion*, a skin.) The outer coverings of the vertebrate ovum and embryo.

CHRYSALIS. (G. *chrusos*, gold.) The "pupa" or second stage of the metamorphosis in insects, such as butterflies and moths. So named from the occasional golden lustre or appearance.

CHYLE. (G. *chulos*, juice.) The nutrient fluid prepared by the digestion of food. The preparatory or primary form of the "blood."

CILIA. (L. *cilium*, an eyelash.) Minute filaments which line the membranes of animals and plants, and which, generally, subserve a circulatory function by their vibratile movements.

CIRRIPEDIA. (L. *cirrus*, a curl; *pes*, foot.) An order of *Crustacea*, in which the feet exist as filamentous organs. Exemplified by the "sea-acorns" and "barnacles."

CNIDÆ. (G. *knide*, a nettle.) The urticating, stinging, or "thread" cells found in most *Cœlenterata*.

CŒLENTERATA. (G. *koilos*, hollow; *entera*, viscera.) A sub-kingdom of animals, possessing a digestive cavity in free communication with the cavity of the body.

CŒNOSARC. (G. *koinos*, common; *sarx*, flesh.) The connecting substance which binds together the zoöids of a *Hydrozoön*.

CONDYLE. (G. *kondulos*, a knuckle.) Applied to the surface or process of a bone which articulates with another bone.

CORPUSCLE. (L. *corpusculum*, a particle.) Applied to the solid particles found in blood, lymph, chyle, and other organic fluids.

CORRELATION, FUNCTION OF. (L. *con*, together; *relatum*, carried back.) The function by means of which animals are brought

into relation with the outside world through their nervous system. Used synonymously with *Innervation* and *Irritability*.

CRUSTACEA. (L. *crusta*, a crust or shell.) The highest class of the *Annulosa*, including the Crabs, Lobsters, etc.

CYCLOSIS. (G. *kuklos*, a circle.) Applied to the circulatory movements seen in cells and in lower organisms. In some cases this circulation is caused by ciliary action; but in other cases its cause is undetermined.

CYST. (G. *kustis*, a bladder.) A sac or vesicle generally containing fluid.

DIATOMACEÆ. (G. *diatemno*, to cut through.) The siliceous or flinty coverings of a large group of microscopic organisms of a low vegetable nature.

DINOSAURIA. (G. *deinos*, terrible; *saura*, lizard.) An extinct order of reptiles, represented by the *Iguanodon*, etc., and which are supposed to present features of relationship with birds.

DIŒCIOUS. (G. *dis*, two; *oikos*, a house.) Applied to organisms in which the sexes are situated in different individuals.

DISTAL. Appplied to the free or unattached extremity of any structure or organism.

ECDYSIS. (G. *ekdusis*, a stripping off.) The process of "moulting," or of changing the skin. Seen typically in the process of metamorphosis.

ECHINODERMATA. (G. *echinos*, a hedgehog; *derma*, skin.) A class of the *Echinozoa* or *Annuloida*, including the sea-urchins and star-fishes. So named from the spiny or hard nature of the integument.

ECTODERM. (G. *ektos*, outside; *derma*, skin.) The outer skin or external body layer of *Cœlenterata*.

EMBRYO. (G. *en*, in; *bruo*, I swell.) The earliest appearance of the future being in an impregnated animal ovum.

ENDODERM. (G. *endon*, within; and *derma*.) The inner skin or internal body layer of *Cœlenterata*.

EPIDERMIS. (G. *epi*, upon; and *derma*.) The outer layer of the skin in the higher animals, and the outer tissue of the leaves of plants.

EPIZOA. (G. *epi*; *zoön*, animal.) Applied to certain lower *Crustaceans*, which exist as parasites on fishes, etc.

FAUNA. (L. *Fauni*, the rural deities of the Romans.) Applied collectively to the entire animal life of a country or zone.

FISSIPAROUS. (L. *findo*, I cleave; *pario*, I produce.) Applied to that asexual form of reproduction, in which new individuals are produced by simple fission, division, or cleavage of the parent body.

Flora. (L. *Flora*, the goddess of flowers.) Applied collectively to the plant life of a district or country.

Foraminifera. (L. *foramen*, a hole ; *fero*, I carry.) An order of *Protozoa*, distinguished by the presence of a limy shell through holes or "foramina," in which, the protoplasm of the body can be protruded.

Fusiform. (L. *fusus*, a spindle ; *forma*, shape.) Pointed at both ends ; spindle-like.

Ganglion. (G. *gagglion*, a swelling.) A mass of nervous matter. constituting a nerve centre, formed of nerve cells, and receiving and emitting impressions.

Gastric. (G. *gaster*, the belly.) Relating to the stomach ; or (in the lower animals) to the digestive system generally.

Gemmiparous. (L. *gemma*, a bud ; *pario*, I produce.) A form of asexual reproduction, in which new individuals are produced as "gemmæ" or "buds" from the parent body.

Geology. (G. *ge*, the earth ; *logos*, discourse.) The science which deals with the form, structure, past history, and present relations of our earth, and of the materials which compose it. *Palæontology* (q. v.) is accounted a subdivision of this wider science.

Germinal Vesicle and Germinal Spot. The nucleated cell and nucleolar particle seen in the unimpregnated ovum, and which lie embedded amid the "vitellus" or "yolk."

Germ Cell. The first cell which appears in the impregnated ovum as the result of successful impregnation.

Gland. (L. *glans*, an acorn.) An organ secreting from the blood certain products which are elaborated by the gland structures, and excreted from the gland generally by a distinct channel or duct.

Gonophore. (G. *gonos*, seed ; *phero*, I carry.) Applied to the reproductive processes or generative zoöids of *Hydrozoa*.

Gonosome. (G. *gonos* ; and *soma*, body.) Applied collectively to the reproductive zoöids of an *Hydrozoön*.

Gonozoöid. (G. *gonos* ; *zoön*, animal ; *eidos*, form.) Generally applied to denote the reproductive zoöid of *Hydrozoa*, when it becomes detached from the parent organism, and exists as a free and independent form. (*See* Medusa.)

Gregarina. (L. *grex*, a flock ; hence *gregarius*.) A genus of parasitic *Protozoa*, represented by the *Gregarina*.

Hæmal. (G. *haima*, blood.) Relating to the blood-vascular or circulatory system.

Hermaphrodite. (G. *Hermes*, Mercury ; *Aphrodite*, Venus.) Applied to organisms the sexes of which are contained in one and the same individual.

Heterogangliata. (G. *heteros*, diverse ; *gagglion*, a swelling.)

Owen's name for the *Mollusca.* Applied in allusion to the irregular condition of their nervous system.

HOMOGANGLIATA. (G. *homos*, similar; and *gagglion.*) Owen's name for the *Annulosa.* Applied in reference to the regular or symmetrical disposition of their nervous axis.

HUMERUS. The single bone composing the "brachium" or "upper arm" of Vertebrata.

HYDRA. (G. *hudra*, a watersnake.) The common "fresh-water polype." The type of the *Cœlenterate* class *Hydrozoa.*

HYDROSOMA. (G. *hudra; soma*, body.) Applied to the entire organism, simple or compound, of a *Hydrozoön.*

HYDROZOA. (G. *hudra; zoön*, animal.) The lower class of *Cœlenterata*, of which the *Hydra* is the type.

IMAGO. (L. *imago*, an image.) Applied by Linnæus to the perfect, winged, and sexual insect.

INCISOR. (L. *incido*, I cut.) The front or "cutting teeth" of *Mammalia*, which are fixed in the "præmaxilla," or front portion of the jaw.

INFUSORIA. (L. *infusum*, an infusion.) The highest class of *Protozoa*, so named from their general occurrence in infusions of organic matter.

INNERVATION. *See* CORRELATION

INTUSSUSCEPTION. (L. *intus*, within; *suscipio*, I receive.) The process by which living beings receive matter or food *within* their bodies from the external world. Opposed to the term *Accretion* (q. v.)

INVERTEBRATA. (L. *in*, without; *vertebra*, a joint of the backbone.) Applied collectively by Lamarck to those groups or sub-kingdoms of the animal series (excepting *Vertebrata*) which are destitute of a backbone or vertebral column.

IRRITABILITY. *See* CORRELATION.

KAINOZOIC. (G. *kainos*, recent; *zoe*, life.) The most recent of the great life-periods into which the palæontologist, from a consideration of the contained fossils, divides the rock-formations of the globe. The Kainozoic fossils, accordingly, approach more nearly than those of all the other periods to existing forms of life.

LARVA. (L. *larva*, a mask.) Linnæus' term for the first or caterpillar stage of insect-life.

MAMMALIA. (L. *mamma*, the breast.) The highest class of *Vertebrata*, distinguished in chief by the possession of mammary or milk glands, by means of which they suckle their young.

MARSUPIALIA. (L. *marsupium*, a pouch.) An order of *Mammalia*, represented by Kangaroos, etc., which possess a "pouch" for the protection of the immature young.

Medusæ. (L. *Medusa*, a Gorgon.) Applied to a group of *Hydrozoa*, represented by the "Jelly-fishes" or "Sea-blubbers;" but the term is sometimes used to indicate the free gonozoöids of many *Hydrozoa*, which closely resemble *Medusæ* in form and habits.

Mesozoic. (G. *mesos*, middle; *zoe*, life.) The middle or Secondary life-period of palæontologists.

Molar. (L. *mola*, a mill.) The teeth in *Mammalia*, which are not preceded by a "milk" or temporary set. The "grinding" teeth.

Mollusca. (L. *mollis*, soft.) Cuvier's name for a sub-kingdom of animals, represented by shell-fish, cuttle-fishes, and other forms.

Molluscoida. (L. *mollusca;* G. *eidos*, like.) The lower group of the sub-kingdom *Mollusca*.

Monœcious. (G. *monos*, single; *oikos*, house.) Applied to organisms in which the sexes are united in one individual. Synonymous with *Hermaphrodite*.

Monothalamous. (G. *monos; thalamos*, a chamber.) Consisting of a single chamber. Generally applied to shells.

Morphology. (G. *morphe*, form; *logos*, a discourse.) The division of biological science which deals with the structure and details of *form* of living organisms. It includes the subdivisions anatomy, development, taxonomy or classification, and histology.

Multilocular. (L. *multus*, many; *loculus*, a little purse.) Consisting of many chambers or divisions.

Nerve. (L. *nervus*, a sinew.) Applied to the branching filaments of the neural or nervous system.

Neural. (G. *neuron*, a cord or "nerve.") Belonging to the nervous system.

Neuter. (L. *neuter*, neither.) Applied to forms (and especially to insects) in which the sex is indistinct or undeveloped.

Normal. (L. *norma*, a rule.) Agreeing with an ordinary type of structure, or with a usual and perfect function.

Notochord. (G. *notos*, back; *chorde*, a string.) The "chorda dorsalis" or "notochord" is a structure found in the early or embryonic life of all *Vertebrata*. It is formed in the floor of the "primitive groove" of the embryo, and is generally replaced in the adult, by the vertebral column or spine; although, in some cases, the "notochord" persists, as such, throughout life.

Nucleated, possessing a "nucleus" (q. v.)

Nucleus. (L. *nucleus*, a kernel.) The solid particle of germinal matter found in the interior of most cells. The "nucleolus" is the smaller particle, occasionally found within the "nucleus."

OCCIPITAL. Belonging to the "occipital" bone, or posterior bone of the vertebrate skull.

ŒSOPHAGUS. (G. *oisos*, a reed; *phagein*, to eat.) The "gullet" or tube leading from the mouth to the stomach.

OVARY or OVARIUM. (L. *ovum*, an egg.) The essential reproductive organ of the female, in which the "ova" or "eggs" are formed.

OVIPAROUS. (L. *ovum; pario*, I produce.) Applied to animals which bring forth eggs from which the young are afterwards hatched.

OVUM. The essential product of the female generative system, generally consisting of an outer membrane, the "vitellary membrane;" a "yolk" or "vitellus;" and a contained vesicle and its particle,—the germinal vesicle and "germinal spot." After impregnation by contact with the male element, the ovum is capable of being developed into a new being.

PALÆONTOLOGY. (G. *palaios*, ancient; *logos*, a discourse.) The department of science (usually forming a subdivision of Geology) which investigates the relations of life in the past, and thus deals with "fossil organisms."

PALÆOZOIC. (G. *palaios; zoe*, life.) The most ancient or Primary life-period, into which the palæontologist divides the series of rock-formations.

PARIETO-SPLANCHNIC. (L. *paries*, a wall; G. *splagchna*, viscera.) Applied to the nervous ganglion in the higher *Mollusca*, which supplies the walls of the body, the heart, gills, and other viscera, with nervous filaments.

PARTHENOGENESIS. (G. *parthenos*, a virgin; *genesis*, generation.) Owen's general term for forms of asexual reproduction (gemmation and fission). But more particularly used to denote cases in which new individuals are produced by females from ova without impregnation by a male.

PEDAL. (L. *pes*, the foot.) Applied to the "foot" nervous ganglion of *Mollusca*. Connected with the foot.

PERIGASTRIC. (G. *peri*, around; *gaster*, the stomach.) Applied to spaces in the body-cavity in *Invertebrata* which surround the stomach and viscera generally. A circulation of fluid is not unfrequently observed to take place through these spaces.

PERIPHERY. (G. *periphereia*, a circumference.) The outer edge or circumference of an organ or structure.

PHALANGES. (G. *phalagx*, a row.) The small bones of the fingers or toes (digits) of *Vertebrata*.

PHYSIOLOGY. (G. *phusis*, nature; *logos*, a discourse.) The division of Biology which investigates the *functions* and mode of life of living beings.

PISCES. (L. *piscis*, a fish.) The lowest class of the *Vertebrata*—the Fishes.

PLACENTA. (L. *placenta*, a cake.) The "after-birth" of *Mammalia*, constituted in chief by the greatly-developed "chorion," and outer membranes of the impregnated ovum. The "placenta" forms the medium of communication between the circulation of the mother and that of the embryo or fœtus.

PLATYRHINA. (G. *platus*, broad; *rhines*, nostril.) Applied to a group of *Quadrumana* or Monkeys, distinguished by having the nostrils broad, and placed far apart. Ex.—Spider-Monkey.

PLUTEUS. (L. *pluteus*, a shed.) Applied to the "larval" form of some *Echinodermata*. The "painter's easel," larva of the *Echinus* or "Sea-urchin."

POLYPE. (G. *polus*, many; *pous*, foot.) Now applied to the "individuals" of single *Actinozoa*, or to the "zoöids" of a compound *Actinozoön*. Formerly, and still popularly used to signify any of the plant-like *Cœlenterata* and other forms.

POLYPIDE. A term now used to designate the "zoöids" of a *Polyzoön* (such as the separate organisms of which a "Sea-mat" is composed). Employed distinctively from "polype" and "polypite."

POLYPIDOM. The entire or common integument or outer skin of a *Hydrozoön* or *Polyzoön*.

POLYPITE. A term applied to designate the nutritive zoöids of any *Hydrozoön*.

POLYTHALAMOUS. (G. *polus*, many; *thalamos*, a chamber.) Many-chambered. Applied principally to the shells of *Foraminifera*.

POLYZOA. (G. *polus*; *zoön*, animal.) The technical name of the *Molluscan* class, which includes the "Sea-mats" and their allies. Synonymously used with the older name of "*Bryozoa*," this latter term meaning "moss-like" animals.

PROTISTA. Hæckel's term for the series of lower organisms, the distinct animal or plant nature of which has not been ascertained. Used synonymously with the term "*Regnum Protisticum*."

PROTOPHYTA. (G. *protos*, first; *phuton*, plant.) A collective term used to designate the lowest plants; *Algæ* or Sea-weeds, etc. etc.

PROTOPLASM. *See* BIOPLASM.

PROTOZOA. (G. *protos*; *zoön*, animal.) The lowest sub-kingdom or type of animal-structure.

PROXIMAL. (L. *proximus*, next.) The fixed or attached extremity of a limb or organism.

PSEUDOPODIA. (G. *pseudos*, false; *poda*, feet.) The prolongations or processes into which certain *Protozoa* (RHIZOPODA, q. v.) can push out the substance of their protoplasmic bodies.

PSEUDONAVICELLÆ. (G. *pseudos*; L. *navicula*, a little boat.) Applied to the spindle-shaped bodies seen in the reproductive development of *Protozoa*, and which form the embryos or young animals. Ex. *Gregarina*.

PTERODACTYL. (G. *pteron*, wing; *daktulos*, finger.) A genus of extinct *Reptiles* distinguished by the great elongation of the fifth finger to form a support for a "patagium" or "wing-membrane."

PTEROPODA. (G. *pteron; pous*, foot.) A class of *Mollusca* represented by minute oceanic organisms, which possess two "wing-like" feet or fins attached to the head.

PUPA. (L. *pupa*, a doll.) The second stage of insect-metamorphosis. Synonymous with "nymph" and "chrysalis."

QUADRUMANA. (L. *quatuor*, four; *manus*, hand.) An order of *Mammalia* represented by the monkeys, apes, lemurs, etc.

RADIATA. (L. *radius*, the spoke of a wheel.) Cuvier's sub-kingdom of animals, now divided into the *Protozoa*, *Cœlenterata*, and *Echinozoa*.

RADIOLARIA. (L. *radius*.) An order of *Protozoa* allied to the *Foraminifera* (q. v.), and distinguished by the possession of a flinty or siliceous shell.

REGNUM PROTISTICUM of Hæckel. (*See* PROTISTA.)

REPTILIA (L. *repto*, I crawl.) A class of *Vertebrata* represented by tortoises, snakes, lizards, and crocodiles.

RHIZOPODA. (G. *rhiza*, root; *pous*, foot.) A class of *Protozoa* distinguished by the power of pushing out the body into root-like processes or "pseudopodia" (q. v.) Ex.—*Amœba*, etc.

RODENTIA. (L. *rodere*, to gnaw.) An order of *Mammalia* represented by the rats, etc. etc., distinguished by the possession of a peculiar dental arrangement suited for gnawing.

ROTIFERA. (L. *rota*, a wheel; *fero*, I bear.) A group of animalcules now included in the *Echinozoal* sub-kingdom, and which possess ciliated discs. When in motion these discs resemble rotating wheels, and hence the name.

SARCODE. *See* BIOPLASM.

SESSILE. (L. *sedo*, I sit.) Applied to any body, structure, or organism destitute of a stalk or pedicle, and which is attached directly to any surface.

SILICEOUS. (L. *silex*, flint.) Composed of silica or flint.

SOMATIC. (G. *soma*, body.) Belonging to the body.

SOMITE. (G. *soma*.) A segment or zone of the body in *Annulosa*. Applied also to any one part of a similar series.

SPERMARIUM. (G. *sperma*, seed.) The essential organ or structure of the "male" reproductive system in which the seminal fluid and spermatozoöids are elaborated. The organ corresponding to the female "ovarium."

SPERMATOZOA (or *Spermatozoöids*). (G. *sperma; zoön*, animal.) The minute living organisms or "animalcules" found in the semi-

nal or spermatic fluid, and in which the fertilising power of male animals is supposed to reside.

SPORES. (G. *spora*, seed.) The usually minute germs or seeds of *Protozoa* and many plants.

STATOBLASTS. (*G. statos*, fixed; *blastos*, a bud.) The "winter-ova" or internal buds of *Polyzoa*, which give origin to new individuals on being set free from the parent-organism.

TÆNIA. (G. *tainia*, a ribbon.) A genus of parasitic worms represented by the "Tape-worm." Type of the family *Tæniada*.

THREAD-CELLS. *See* CNIDÆ.

TROPHOSOME. (G. *trepho*, I nourish; *soma*, body.) The collective term for the series of "nutritive" zooids of any *Hydrozoön*. Used distinctively to "gonosome" (q. v.)

TUNICATA. (L. *tunica*, a garment.) The class of Lower *Mollusca*, represented by the "Sea-squirts" or *Ascidians*.

UMBILICAL SAC OR VESICLE. (L. *umbilicus*, the navel.) The embryonic sac of *Vertebrata*, developed from the "mucous" layer of the germ, and which is devoted chiefly to the nutrition of the young form.

UMBRELLA. The round contractile disc or "bell" of many *Hydrozoa*; characteristically seen in *Medusæ* (q. v.)

UNILOCULAR. (L. *unus*, single; *loculus*, a little purse.) Consisting of one chamber.

VACUOLES. (L. *vacuus*, empty.) The minute clear spaces seen in the sarcode bodies of many *Protozoa*, and caused by the digestion of food.

VASCULAR. (L. *vas*, a vessel.) Relating to the hæmal or circulatory system. A "vascular" structure is one plentifully provided with bloodvessels.

VENTRAL. (L. *venter*, the belly.) Applied to the lower or inferior surface of any body or organism.

VERTEBRA. (L. *vertebra*, from *vertere*, to turn.) One of the joints or separate bones of the spine or backbone of *Vertebrata*.

VERTEBRATA. (L. *vertere*.) The highest sub-kingdom of animals, distinguished in chief by the possession of a spine or backbone. Used distinctively to *Invertebrata* (q. v.)

VESICLE. (L. *vesica*, a bladder.) A sac or cyst generally containing fluid, but occasionally applied to denote certain glandular structures.

VIBRIO. (L. *vibro*, I quiver.) Applied to minute organisms of vegetable nature found in infusions of organic matter.

VILLUS. (L. *villus*, a tuft of hair.) Applied to minute processes of membranes throughout the animal economy. And specially to the vascular processes developed upon the "chorion" (q. v.)

of *Vertebrata*, which subsequently developes in the higher forms into the "placenta."

VITELLUS. (L. *vitellus*, the yolk of an egg.) The "yolk" or "yelk" of all ova. Surrounded by the "vitellary membrane" or "yolk-sac."

VIVIPAROUS. (L. *vivus*, alive; *pario*, I produce.) Applied to those animals (*e.g.* Mammalia), which bring forth their young alive.

ZOÖID. (G. *zoön*, animal; *eidos*, resemblance.) A term now applied to designate the separate beings of compound organisms (*e.g.* Sea-mat), which are produced by budding, or by fission from a parent form. The zoöids may either be connected with, or entirely detached from the parent.

ZOOPHYTE. (G. *zoön*; *phuton*, plant.) A popular term for plant-like animals, such as the *Hydrozoa*, Sea-mats, Corals, etc.

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THE END.

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